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—NOTICE TO SUBSCRIBERS—

—Copies of February Journal Needed—

The unprecedented demand for the articles on DDT absorbed all of the separates and before we knew it all the extra copies of the Journal. We must have 35 copies of the February Journal, Volume 37, No. 1 to complete a standing order for libraries. It occurs to the writer that some subscribers might be willing to sell us their copy of the February 1944 Journal possibly after the close of the year or after they have read and used it for reference during the year. We will be glad to pay 75¢ per copy for any that can be spared or to credit the amount on the individual's 1945 subscription.

The Sixth Edition of ENTOMA is under preparation.

See page vi, this issue.

JOURNAL OF ECONOMIC ENTOMOLOGY
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VOL. 37 December, 1944 No. 6

Insecticide Tests for Bollworm Control[1]

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Texas cotton planters have not been entirely successful in economically controlling the bollworm, *Heliothis armigera* (Hbn.), with commercial calcium arsenate. Careful investigations have been made during recent years in an effort to find a material which can be substituted for calcium arsenate in the control of this pest. Specially prepared calcium arsenate containing larger particles and higher percentages of water-soluble arsenic pentoxide or calcium arsenate-paris green mixtures have not (Gaines 1939; Gaines & Dean 1942) proven any better than a commercial calcium arsenate. Investigations (Ewing and Moreland 1942; Moreland *et al.* 1941; Gaines 1941) have shown that the use of basic copper arsenate, lead arsenate, and cryolite gave better control of the bollworm and a smaller increase in aphid populations than commercial calcium arsenate. These materials did not, however, prove to be as effective as calcium arsenate against the boll weevil *Anthonomus grandis* Boh., which often occurs in injurious numbers simultaneously with the bollworm. The arsenicals were more effective against the weevil than was cryolite and losses in yields occurred when cryolite was depended upon to control this pest.

Additional tests were conducted at College Station during 1942, using these materials and other promising new or substitute materials for the economical control of the bollworm. Due to the scarcity of arsenic a calcium arsenate containing a low percentage of arsenic pentoxide was included in one of the experiments in order to determine the possibility of reducing the proportion of arsenic and at the same time obtaining a profitable gain in yield. The specially prepared calcium arsenates tested in previous years, which contained high percentages of water-soluble arsenic pentoxide and large particles, had poor dusting qualities. The material used this year in experiment No. 2 contained a high percentage of water-soluble arsenic pentoxide and small particles and had as good dusting qualities as commercial calcium arsenate. The results of these tests as well as a comparison of gains made with various insecticides during a 7-year period are given herein.

FIELD PLOTS AND TREATMENTS.—In experiment No. 1 the plots were arranged in randomized blocks and each treatment was replicated four times. The dusting area of each plot was one-tenth acre (13 rows wide) and the picking area, after the buffers were eliminated was one-twentieth acre. The following insecticides were used: commercial calcium arsenate containing 42.0 per cent total arsenic pentoxide and 2.7 per cent water-soluble arsenic pentoxide (N. Y. method) and having a mean-surface particle diameter of 1.0 micron as determined by the air permeation method; calcium arsenate containing only 15.5 per cent total arsenic pentoxide and 0.2 per cent water-soluble arsenic pentoxide; lead arsenate containing 31.9 per cent total arsenic pentoxide and 0.3 per cent water-soluble arsenic pentoxide; copper hydroarsenate containing 16.8 per cent total arsenic pentoxide or 41.3 per cent copper arsenate; and basic copper arsenate containing 36.6 per cent total arsenic pentoxide or 90.1 per cent copper arsenate. The latter material was mixed with *Pyrax* 50-50, to improve the dusting qualities. Seven effective applications were made at approximately 5-day intervals from June 30 to August 4. All materials were applied

[1] Technical contribution No. 764, of the Texas Agricultural Experiment Station in cooperation with the Bureau of Entomology and Plant Quarantine.

[2] W. S. McGregor, W. A. Bilsing, J. T. Bonnen, W. J. Magee, G. T. Davis, and W. H. Allison assisted in taking the field notes. Chemical analyses of the insecticides were made by the Division of Insecticide Investigations, Bureau of Entomology and Plant Quarantine, Agricultural Research Administration, U. S. Department of Agriculture.

at the rate of from 7.5 to 9.5 pounds per acre per application except basic copper arsenate-*Pyrax* which was applied at 17 pounds per acre.

In experiment No. 2 also, the plots were arranged in randomized blocks and each treatment was replicated three times. The plot size was the same as that used in experiment No. 1. The insecticides were: lead arsenate and basic copper arsenate as used in experiment No. 1; cryolite-sulfur containing 73.4 per cent sodium fluoaluminate; commercial calcium arsenate containing 42.4 per cent total arsenic pentoxide and 3.2 per cent water-soluble arsenic pentoxide with a mean-surface diameter (by air permeation) of 1.0 microns, and a special calcium arsenate containing 43.1 per cent total arsenic pentoxide and 19.2 per cent water-soluble arsenic pentoxide having a small particle size with a mean-surface diameter (by air permeation) of 0.7 microns. Eight applications were made at approximately 5-day intervals from July 19 to August 20. One application was completely washed off by rains and the efficiency of two others was reduced. All materials were applied at the rate of from 6.8 to 9.8 pounds per acre per application except basic copper arsenate-*Pyrax* which was applied at 17.5 pounds per acre. All plats were dusted with a 3 per cent nicotine dust for aphid control on August 20.

RECORDS.—The infestation records were made at approximately 5-day intervals in the following manner. One hundred squares were examined on consecutive plants in each plat and the percentage punctured by weevils recorded. One hundred squares and 100 bolls were examined in each plat for bollworm injury and the per cent injured forms recorded. Aphid counts were made by recording the number of aphids on a square inch of leaf area in the center of the fourth leaf from the top on 100 consecutive plants in each plat. The numbers of rapid plant bugs found on the squares examined for boll weevil punctures were recorded.

Table 1.—Average cotton insect infestation and yields of seed cotton following the different treatments, College Station, Texas, 1942.

Treatment	Boll Weevil Infestation		Bollworm Injury		No. Rapid Plant Bugs per 100 Squares	Number Aphids per Sq. Inch	Pounds Seed Cotton	
	Per Cent of Sqs. Punctured	Equivalent Angles	Per Cent of Forms Injured	Equivalent Angles			Per Plat	Per Acre
			Experiment 1					
Check	13.6	21.50	13.8	21.82	6.4	2.09	41.74	835
Commercial calcium arsenate	5.9	13.98	6.4	14.61	5.0	11.52	57.89	1158
Calcium arsenate (low)	7.2	15.48	8.6	16.99	5.8	4.10	51.20	1024
Lead arsenate	7.6	15.99	5.3	13.27	4.0	7.90	63.30	1266
Copper hydroarsenate	7.1	15.45	11.0	19.34	3.4	7.90	55.13	1103
Basic copper arsenate-*Pyrax* (1:1)	6.2	14.34	3.6	10 84	4.4	6.20	67.83	1357
Minimum significant difference[1]	—	2.32	—	1.73	1.88	3.62	5.90	—
			Experiment 2					
Check	5.2	12.93	23.6	28.92	3.2	6.65	18.08	362
Commercial calcium arsenate	2.8	9.61	10.8	19.05	1.2	12.50	41.50	830
Special calcium arsenate[2]	2.6	9.31	12.3	20.46	.8	22.71	32.73	656
Cryolite-sulfur	2.5	9.11	8.2	16.66	2.4	5.13	48.05	961
Lead arsenate	2.8	9.28	8.8	17.26	1.6	9.24	47.00	940
Basic copper arsenate-*Pyrax* (1:1)	1.6	7.19	6.0	14.13	1.4	9.30	51.48	1030
Minimum significant difference[1]	—	2.78	—	3.43	—	9.40	18.3	

[1] 5 per cent level.
[2] Small particle size and high percentage water-soluble arsenic.

RESULTS.—The seasonal averages of the boll weevil, bollworm and rapid plant bug infestation made periodically during the dusting period on all replicates of both experiments are shown in table 1. The aphid infestations after 6 applications on experiment No. 1 and seven applications on experiment No. 2 and the average plat yields and calculated acreage yields are also shown. The percentages of weevil and bollworm injury were transformed into angles before analysis of variance was carried through. The results of the statistical analyses are summarized in table 2. In all but one case the F-test indicated that there were significant differences between treatment means. For comparison of the means the significance of differences between treatments is shown in table 1.

In experiment No. 1 basic copper arsenate gave significantly better control of bollworms than any of the other materials used. Commercial calcium arsenate was approximately as effective as lead arsenate and both gave better control than copper hydroarsenate or calcium arsenate containing a low percentage of arsenic. Using yields as a criterion, lead arsenate was approximately as effective as basic copper arsenate although the latter was significantly better than commercial calcium arsenate, or calcium arsenate containing a low percentage of arsenic or copper hydroarsenate. It is interesting to note that the yield on the copper hydroarsenate plats was higher than that on the plats dusted with a calcium arsenate containing a low percentage arsenic pentoxide, although the weevil infestation was about the same and the bollworm injury as well as the aphid infestation was higher. Since this increase cannot be explained by the records of infestation it is assumed that the copper in the insecticide acted in some manner to stimulate fruit production. If the arsenic supply remains scarce, it is quite possible that calcium arsenate with a lower arsenic pentoxide content, even as low as one-half of the present standard, may prove to be important.

In experiment No. 2 basic copper arsenate, lead arsenate and cryolite were approximately equally effective against the bollworm. Basic copper arsenate also gave significantly better control than the calcium arsenates. On the basis of yields, basic copper arsenate, cryolite and lead arsenate were about equally effective. These materials gave higher yields than the calcium arsenates but these differences were not significant. The commercial calcium arsenates and those with higher water-soluble arsenic contributed to higher increases in aphids, indicating that the high percentage water-soluble arsenic contributes to high aphid populations. From August 10 to 24 the bollworms were most injurious and difficult to control. During this period, 3 applications of insecticides were made and 11 showers of rain were recorded. The effectiveness of all these applications was greatly impaired by showers. The infestation records as shown in (Fig. 1) indicate the comparative

Table 2.—Analyses of data shown in table 1.

EXPERIMENTS AND SOURCE OF VARIATION	DF	MEAN SQUARE PERTAINING TO— Boll Weevil Infestation Angles	Bollworm Injury Angles	Aphid Population	Rapid Plant Bug Population	Yield
			Experiment 1			
Blocks	3	10.84	2.81	10.85	7.22	62.55
Treatments	5	30.10**	65.52**	43.50**	5.00*	338.95**
Error	15	2.38	1.30	5.77	1.54	15.33
Total	23	12.87	15.46	14.63	3.03	91.84
			Experiment 2			
Blocks	2	15.38	20.14	17.12	3.34	126.06
Treatments	5	10.41*	79.06**	119.20*	2.26	468.51*
Error	10	2.35	3.57	26.74	1.38	101.21
Total	17	9.61	27.72	52.80	1.87	212.16

* Significant.
** Highly significant.

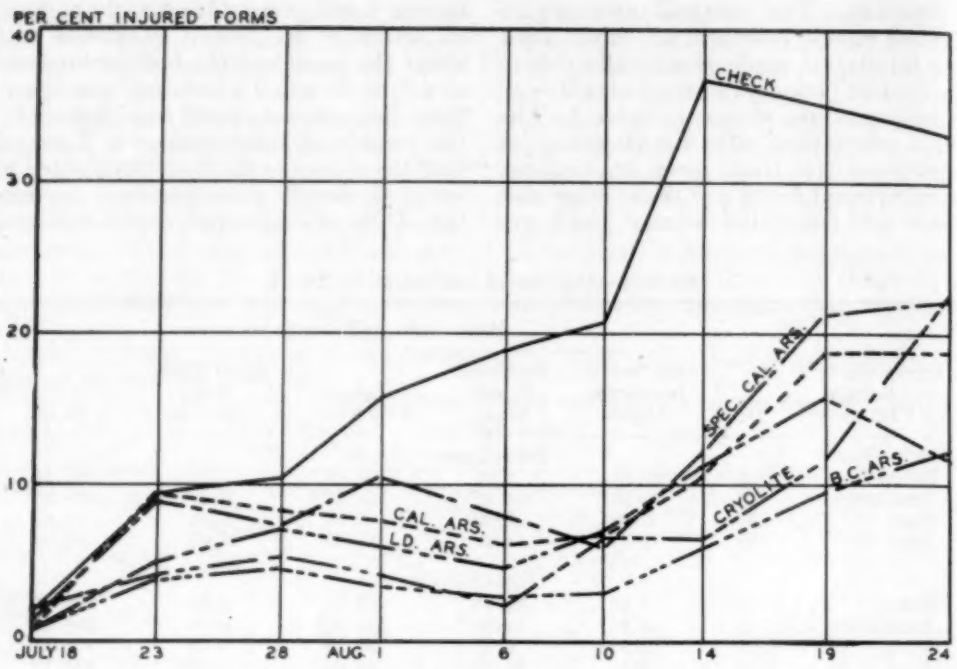

FIG. 1.—The average percentage of forms injured by bollworms on plats receiving treatments as indicated, College Station, Texas, 1942.

Table 3.—Average gains in pounds of seed cotton per acre of treated plats over check plats due to bollworm and boll weevil control using the most promising insecticides as indicated, College Station, Texas.

			Insecticides Used							
Year	No. Replications	No. Effective Applications	Commercial Calcium Arsenate	Special Calcium Arsenate[3]	Calcium Arsenate + Paris Green (93–7)	Cryolite Sulfur (85–15)	Alternate Applications Calcium Arsenate and Cryolite[1]	Lead Arsenate	Alternate Applications Calcium Arsenate Lead Arsenate[1]	Basic Copper Arsenate *Pyrax* 1:1
1936	5	9	360		444					
1938[2]	5	4		228	263					
1938[2]	4	4	228							
1939	3	4	243			178				
1939	3	7	501	654						
1940	5	8	385	458		351				
1940	3	8	368			349		486		
1940	6	6	349			296		344		
1941	4	11	626	470						
1941	3	9	621							
1941	2	6	445				312		532	
1941	4	9							659	
1942[2]	4	7	323					431		522
1942[2]	3	7	468	294		399		578		668
1942	4	5							340	
Ave. gain per application			57	57	54	54	52	66	77	85

[1] Alternate applications using two applications of cryolite or lead arsenate as indicated during the period bollworm injury was highest.

[2] Gains due principally to bollworm control. Weevils present but not in sufficient numbers to be considered injurious. In 1940, weevils did not become injurious until very late in season, other years weevil control contributed to increases in yields.

[3] Large particle size and high water-soluble arsenic pentoxide in 1938, 1939, 1940 and 1941. Small particle size and high water-soluble arsenic pentoxide in 1942.

effectiveness of the materials in showery weather. Basic copper arsenate and lead arsenate seemed to be more effective than the other materials. Cryolite was effective until the latter part of the period during which time the number of showers was greatest.

The gains in yields resulting from the use of various insecticides in experiments during the last 7 years are given in table 3. Some of these gains were partially due to weevil control, but no experiments are included in which the weevil was the only pest affecting the yield. The bollworm was the major pest in most of the experiments and in some as indicated it was the only pest of importance. In all the experiments calcium arsenate has proven profitable against the bollworm, but not as profitable as some of the other insecticides. Cryolite is effective against bollworms but yields are reduced when weevils occur in injurious numbers. The smaller gains due to cryolite have been due to poor weevil control. Lead arsenate is more effective against weevils than cryolite and more effective against bollworms than calcium arsenate; and when used for both weevil and bollworm control when the latter particularly is injurious, the yields are higher than when either of the other materials is used exclusively. In 1942 basic copper arsenate proved to be the most effective against bollworms of any of the insecticides included in the experiments. The high yields resulting from the use of this insecticide appear to be partially due to the presence of the copper. The two treatments resulting in highest gains were basic copper arsenate and alternate applications of calcium arsenate with lead arsenate in a schedule of applications for weevil and bollworm control. When bollworms occurred alone high gains were also made with cryolite and lead arsenate.—10-7-44.

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ORCHIDS TO DR. CORY

At the annual Meeting of the Maryland Nurserymen's Association, Dr. E. N. Cory was the honor guest at a special luncheon. The occasion of this luncheon was the completion by Dr. Cory, of a period of 35 years work in cooperation with the Nurserymen of Maryland.

Among the many activities of Dr. Cory one less known to his fellow entomologists is an active interest in orchids and their culture. As a special testimonial to this interest a new orchid, the first flower of a newly originated variety, was presented to him and the variety was named in his honor, the "Dr. Ernest N. Cory." This, in the words of the toastmaster, was "in appreciation of untiring work for the orchid industry."

In addition, a gold watch was presented to Dr. Cory by the Association.

The luncheon was attended by Dr. H. C. Byrd, President of the University of Maryland, Dr. T. B. Symons, long a member of our Association and Dr. Cory's predecessor as State Entomologist, and Dr. F. C. Bishopp who attended as the representative of the Bureau of Entomology and Plant Quarantine.

Control of the Cotton Aphid with Different Forms of Rotenone and Nicotine[1]

J. C. GAINES,[2] *Texas Agricultural Experiment Station, A. & M. College of Texas*

Infestations of cotton by the cotton aphid, *Aphis gossypii*, have been recognized as a hazard which develops after calcium arsenate has been applied to cotton for the control of other insects. This problem is apparently more serious in the southeastern section of the cotton belt than in Texas. In certain years, however, serious aphid infestations have developed following applications of calcium arsenate in this State. In a number of instances

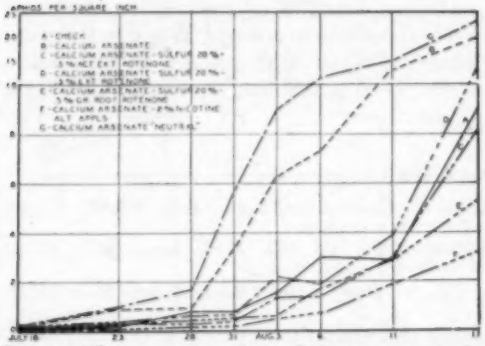

FIG. 1.—The average number aphids per square inch on leaves in plats receiving treatments as indicated. Experimental plats at College Station, Texas, 1942.

these infestations occurred late in the season and have caused only slight losses in yield, although they have reduced the quality of the cotton. In 1941 plats treated with calcium arsenate–rotenone mixture made higher yields than those treated with calcium arsenate alone (Gaines 1943).

Tests were conducted during 1942 of "activated" rotenone, the usual forms of rotenone, and nicotine sulfate to determine their comparative efficiency when mixed and applied with calcium arsenate dust in preventing aphid infestation. In another test the effectiveness of several materials in "clean up" control of aphid infestation was compared. The results of these tests are herein given.

Three replications of the following materials were used on 0.02 acre plats of five rows each 50 feet long: commercial calcium arsenate; commercial calcium arsenate with 20 per cent sulfur and 0.5 per cent "activated" rotenone (extractive); commercial calcium arsenate with 20 per cent sulfur and 0.5 per cent rotenone (extractive); commercial calcium arsenate containing 20 per cent sulfur and 0.5 per cent rotenone (ground root); alternate applications of commercial calcium arsenate and commercial calcium arsenate containing 2 per cent nicotine (nicotine sulfate); and a so-called "neutral" calcium arsenate (pH 9.80). Nine early morning applications at 5-day intervals during July and August were made at the rates shown in table 1. The average number of aphids per square inch and the average weevil and bollworm infestations during the dusting period for each group of replicated plats also are shown in table 1 along with the yields. Comparisons of the seasonal aphid development are shown in figure 1. Apparently the size of the plats was adequate to obtain information on the effectiveness of the materials especially during the development period until August 11.

The calcium arsenate–sulfur–rotenone mixtures were effective in preventing the increased development of aphids which occurred when calcium arsenate alone was applied. But these mixtures were not as effective in controlling aphids as the alternating applications of calcium arsenate and calcium arsenate containing 2 per cent nicotine. Apparently an average of more than 8 or 9 aphids per square inch of leaf surface on the upper leaves of the plant during the dusting period would have been necessary to influence the yield in this experiment.

Only small differences among the various treatments were shown by the means of boll weevil infestation, bollworm injury or yield. Apparently the addition of sulfur and rotenone or nicotine did not affect the toxicity of the calcium arsenate to weevils or worms. The "neutral" calcium arsenate gave better bollworm control and a little higher yield than the standard.

[1] Technical contribution No. 774, Texas Agricultural Experiment Station.

[2] W. S. McGregor, W. A. Bilsing, J. T. Bonnen, W. J. Magee, G. T. Davis and W. H. Allison assisted in taking the field notes. In cooperation with the Bureau of Entomology and Plant Quarantine.

Table 1.—Average cotton insect infestation during the dusting period and yield in pounds seed cotton, in experimental plats, College Station, Texas, 1942.

TREATMENT	AVE. LBS. PER ACRE APPLICATION	AVE. BOLL WEEVIL INFESTATION (PER CENT)	AVE. BOLLWORM INJURY (PER CENT)	AVE. NO. APHIDS PER SQ. IN. OF LEAF	YIELD IN POUNDS PER ACRE
Check		10.9	17.8	2.31	588
Calcium arsenate	9.6	8.4	9.4	6.46	873
Calcium arsenate sulfur (20%)–rotenone (0.5%) (activated extractive)	10.4	7.2	10.9	1.89	877
Calcium arsenate sulfur (20%)–rotenone (0.5%) (extractive)	9.9	9.8	8.2	2.94	918
Calcium arsenate sulfur (20%) rotenone (0.5%) (ground root)	9.4	7.5	9.4	1.56	963
Calcium arsenate and Calcium arsenate with nicotine (2%) (Alternate applications)	9.3	7.7	7.8	0.93	962
Calcium arsenate–"neutral"	8.2	7.4	7.3	8.31	972

In the test designed as a "clean up" operation, the following aphicides were used to control a heavy infestation of aphids which had developed following applications of calcium arsenate; rotenone dust, containing 0.5 per cent "activated" rotenone (extractive); rotenone dust containing 0.5 per cent rotenone (ground root); nicotine dust containing 0.5 per cent nicotine; rotenone–nicotine dust containing 0.25 per cent rotenone and 0.25 per cent nicotine; nicotine dust containing 3 per cent nicotine (nicotine sulfate); and nicotine dust containing 3 per cent nicotine (free nicotine). Each treatment was duplicated using eighth-acre plats. The results of these tests are shown in table 2 in which it may be seen that the 3 per cent nicotine dusts were more effective than the rotenone dust in a "clean up" application for aphid control.

Table 2.—Average aphid infestation and percentage control for respective treatments, in experimental plats, College Station, Texas, 1942.

TREATMENTS	APHIDS PER SQUARE INCH: Initial Infestation 8/5	APHIDS PER SQUARE INCH: Infestation after dust application 8/7	PER CENT CONTROL[1]
Check	28.24	47.05	
Rotenone Dust (0.5% rotenone "active" extractive)	27.04	27.62	38.7
Rotenone Dust (0.5% rotenone ground root)	29.50	21.12	57.0
Rotenone-Nicotine Dust (0.25% rotenone, 0.25% nicotine)	23.31	26.91	30.7
Nicotine Dust (0.5% nicotine)	18.19	17.52	42.2
Nicotine Dust 3% (free nicotine)	19.34	4.57	85.8
Nicotine Dust 3% (nicotine sulfate)	20.12	3.33	90.0

[1] Abbott's formula.

As an aphid preventive, alternate applications of calcium arsenate and calcium arsenate containing 2 per cent nicotine were most effective. Apparently there was no benefit from the "activated" rotenone over the usual forms. That all rotenones retarded aphid development is shown by the fact that the infestation in the plats treated with these materials did not exceed that found on the untreated checks during the development period.

It has been determined from these and other experiments that, on most fertile soils where several applications of calcium arsenate are nearly always needed for insect control, alternate applications with calcium arsenate containing 2 per cent nicotine for the control of the cotton aphid should prove profitable, but, that on the upland soils where fewer applications are needed, a single "clean up" application may be relied upon to control infestations of this pest in those years when it becomes injurious.—10-7-44.

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Effect of Mineral Oil Containing an Insecticide on the Tips of Sweet Corn Ears

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The mineral-oil treatment for control of the corn earworm, *Heliothis armigera* (Hbn.), in sweet corn has been discussed critically by several workers because the length of the undeveloped tips of the ears was increased as a result of the treatment. Although this effect has been recognized for several years by the writer, it was believed that the resulting loss was of minor importance as compared with the improvement in quality, quantity, and value of the crop resulting from the proper application of the treatment. On the other hand, among the several hundred fields of sweetcorn and plots in which the writer has worked over a period of years, a few instances have been observed in which fully developed kernels were rounded over the tip of almost every treated ear, indicating that in these cases the treatment had had no inhibiting effect on development of the tip kernels. It seemed worth while, therefore, to determine the factors responsible for the increase in undeveloped tips of oiled ears and to find ways of remedying this defect in the control measure. This subject was investigated in the Coachella Valley of California and in Canyon County, Idaho, in 1942.

Undeveloped Tips of Oiled Ears in Commercial Fields.—To obtain records of the extent of undeveloped tips in commercial fields, ears of Golden Cross Bantam sweet corn that had been oiled by the growers and harvested from two fields in the Coachella Valley during the first week of June were examined. A white oil of 100/115 seconds viscosity Saybolt, containing 0.2 per cent pyrethrins, had been applied at a dosage of 0.75 cc. per ear about 10 days before harvest. Five hundred primary ears from each field, each ear bearing a red paint mark indicating that it had been oiled, were taken from the grading belt. The lengths of the undeveloped tips were measured to the nearest tenth of an inch. For comparison, similar measurements of 500 primary ears from a comparable untreated field of the same variety were also made. The results are given in table 1, and show that the undeveloped tips of the oiled ears from the two treated fields averaged 0.3 and 0.4 inch longer, respectively, than those of ears from the untreated field. As compared with untreated ears, the increase in the undeveloped tips of oiled ears 6, 7, or 8 inches long represented kernel losses of 4.3, 3.7, and 2.9 per cent, respectively, in one field, and 6.2, 5.3, and 4.6 per cent, respectively, in the other.

Table 1.—Comparison of the length of the undeveloped tips of oiled and untreated ears of Golden Cross Bantam sweet corn from commercial fields in the Coachella Valley, Calif., 1942. Five hundred ears from each treatment were examined.

Treatment	Ears in Which the Undeveloped Tips Extended the Following Distances (in Inches) Below the Tip of the Cob						Average Length of Undeveloped Tip	Average Increase Due to Oiling
	0	0.1–0.5	0.6–1.0	1.1–1.5	1.6–2.0	Greater than 2.0		
	Per Cent	*Per Cent*	*Per Cent*	*Per Cent*	*Per Cent*	*Per Cent*	*Inches*	*Inches*
Untreated	14.2	16.0	46.8	18.2	4.6	0.2	0.7	—
Oiled	1.0	7.2	47.8	36.2	6.8	1.0	1.0	0.3
Do.	.8	5.0	41.2	38.0	13.0	2.0	1.1	.4

Effect of Dosage of Oil per Ear.—To evaluate the effect of dosages ranging from 0.25 to 1.50 cc. per ear, white oil of 125/135 seconds viscosity containing insecticides was applied to ears in 2 fields of Golden Cross Bantam sweet corn. Seven replications of 25 ears each per dosage were treated in each field when wilted or partly browned silks indicated that pollination was complete. The average lengths of undeveloped tips at the time of roast-

ing-ear harvest are given in table 2 (last column) and show that in each field the extent of the undeveloped tip increased proportionately with the increase in the dosage of oil. The average increase in undeveloped tips resulting from applications of 0.25, 0.50, 0.75, 1.00, 1.25, and 1.50 cc. their husks beyond the tip of the cob were measured in tenths of an inch. The results are summarized in table 2 and show that, on an average, the increase in length of undeveloped tips caused by applications of oil was proportionately greater as the husk extension was less. The average

Table 2.—Comparison of the average length of the undeveloped tip per ear with the extension of the husk beyond the cob at the time of roasting-ear harvest in Golden Cross Bantam sweet corn to which oil or oil containing an insecticide was applied at dosages of 0.25 to 1.50 cc. per ear. Coachella Valley, Calif., 1942. Ears examined varied from 147 to 174 for each test. Untreated ears numbered 121 and 69, fields 1 and 2.

Dosage per Ear (cc.)	Average Length of Undeveloped Tips in Ears Having the Following Husk Extension					
	0.1–1.0	1.1–2.0	2.1–3.0	3.1–4.0	4.1–5.0	Average per Ear
	Inches	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*
			Field 1			
0.25	—	0.69	0.69	0.66	0.72	0.68
.50	—	.92	.75	.66	.67	.73
.75	—	1.13	1.00	.88	.91	.97
1.00	—	1.44	1.35	1.10	.84	1.23
1.25	—	1.71	1.44	1.35	1.43	1.46
1.50	—	1.70	1.57	1.32	1.05	1.49
.75[1]	—	1.41	1.27	1.15	1.11	1.25
All dosages	—	1.28	1.16	1.00	.95	1.12
Untreated	—	.74	.78	.70	.57	.74
			Field 2			
.25	1.05	.85	.69	.79	—	.80
.50	1.08	1.02	.91	.86	.67	.93
.75	1.31	1.18	1.09	.75	—	1.09
1.00	1.21	1.26	1.13	.99	.95	1.16
1.25	1.72	1.51	1.18	1.14	.92	1.34
1.50	1.82	1.76	1.47	1.26	.95	1.61
.75[1]	1.50	1.66	1.50	1.44	1.98	1.52
All dosages	1.41	1.31	1.15	1.12	1.06	1.22
Untreated	.60	.66	.77	.77	—	.71
			Both Fields			
Oiled	1.41	1.30	1.15	1.04	.96	1.17
Untreated	.60	.69	.78	.71	.57	.73

[1] Ears bearing a tuft of fresh silk when oiled.

per ear was 0, 0, 0.2, 0.5, 0.7, and 0.8 inch, respectively, in the first field and 0.1, 0.3, 0.4, 0.5, 0.6, and 0.9 inch, respectively, in the second field. For all treated ears the average undeveloped tip was 0.4 inch longer than the average for all untreated ears.

EFFECT OF HUSK EXTENSION.—At the time measurements were made of the undeveloped tips of the ears mentioned in the preceding paragraph the extensions of length of undeveloped tips in treated ears was 0.5 inch less in ears having husk extensions of 4.1 to 5.0 inches than in ears having husk extensions of 0.1 to 1.0 inch. In comparison with the undeveloped tips of untreated ears having the same husk extension, the treated ears having the shortest husk extension were affected most. In ears having husk extensions of 0.1 to 1.0 inch the undeveloped tips averaged 0.9 inch longer in treated than in un-

treated ears, whereas in ears having husk extensions of 3.1 to 4.0 inches the undeveloped tips in treated ears averaged only 0.3 inch longer than in untreated ears.

EFFECT OF TUFTS OF FRESH SILK OF A SECONDARY GROWTH.—It has been commonly observed that a tuft of fresh silk occurs in the center of a brown silk mass in sweet-corn ears. This fresh silk, which may appear at any time up to 2 weeks after exposure of the principal silk mass, represents a secondary growth of the tip of the cob often stimulated by soil moisture becoming available from rainfall or irrigation between the time of silking and that of roasting-ear harvest. The effect on the undeveloped tips of applications of 0.75 cc. of oil to ears of this type is shown in table 2. In each field the undeveloped tips of such ears averaged 0.4 inch longer than in normal ears in the same stage of development that received the same dosage of oil.

Table 3.—Length of undeveloped tips in ears of sweet corn to which white oil containing 0.2 per cent of pyrethrins was applied at a dosage of 0.75 cc. per ear on the 6th to 10th days after silk exposure. Canyon County, Idaho, 1942.

Average Length of Undeveloped Tips in Ears Oiled on the Following Days after Silk Exposure						Average Length Untreated Ears
6th	7th	8th	9th	10th	Average	
Inches	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*
Marcross C13×C6, Fields 1–4, incl.						
1.30	0.74	1.03	0.70	0.46	0.82	0.23
.48	.61	.73	.58	.42	.56	.33
.48	.52	.47	.56	.74	.62	.28
.51	.36	.18	.42	.44	.38	.18
Average Fields 1–4, incl.						
.66	.58	.56	.59	.53	.58	.25
Golden Cross Bantam, Fields 5–16, incl.						
.73	.62	.73	.67	.49	.65	.59
1.28	.99	.96	1.08	.90	1.04	.48
.84	.67	.77	.64	.62	.71	.61
1.37	.78	.73	.90	.76	.91	.58
.51	.48	.62	.35	.25	.44	.39
.61	.81	.53	1.13	1.01	.82	.71
.41	.81	.34	.88	.69	.63	.29
.37	1.11	.89	1.12	.72	.84	.44
1.33	1.37	1.49	1.09	1.29	1.31	.78
1.03	.77	1.25	.92	.98	.99	1.04
.92	1.10	1.27	1.07	.72	.99	.72
.82	1.03	.78	.75	1.11	.90	1.11
Average Fields, 5–16, incl.						
.85	.88	.86	.88	.79	.85	.62
Narrow Grain Hybrids, Fields 17–21, incl.						
1.30	1.26	1.36	1.48	1.28	1.34	1.36
1.61	1.46	1.61	1.59	1.53	1.56	1.62
.91	1.13	.95	.97	.97	.98	1.08
1.38	1.03	.73	.58	1.01	.94	1.52
1.42	1.85	1.65	1.39	1.24	1.51	1.36
Average Fields 17–21, incl.						
1.32	1.35	1.26	1.21	1.21	1.27	1.39
Country Gentlemen Hybrids, Fields 21–26 incl.						
.76	.53	.47	.61	.42	.56	.49
1.47	1.36	.91	1.01	1.06	1.16	.52
1.92	1.32	1.29	1.55	1.24	1.45	1.38
1.20	1.22	.89	1.33	1.22	1.17	1.16
.90	.62	1.09	.91	.92	.89	.54
Average, Fields 21–26, incl.						
1.28	.97	.94	1.08	.96	1.03	.97
Oregon Evergreen O.P., Field 27						
1.40	1.18	1.44	1.10	1.18	1.27	.95
Country Gentleman O.P., Field 28						
.92	1.09	.98	.72	.87	.92	1.05
Carmelcross (P39×C15), Field 29						
.36	.36	.39	.30	.50	.38	.66
Average, All varieties						
.97	.94	.91	.91	.86	.92	.82

EFFECT OF INSECTICIDES IN THE OIL.—The ears of two replications in the fields mentioned in table 2 were treated with white oil of 125/135 seconds viscosity containing 0.2 per cent of pyrethrins, in two replications they were treated with oil containing 2 per cent dichloroethyl ether, in two replications they were treated with oil containing 2 per cent ethylene dichloride, and in one replicate oil alone was applied. The average length of undeveloped tips of all ears treated with these materials irrespective of dosage or husk length was 1.13 inches for ears to which oil alone was applied, 1.13 inches for ears treated with oil containing 0.2 per cent of pyrethrins, 1.11 inches for ears that received oil containing 2 per cent of dichloroethyl ether, and 1.14 inches for ears to which oil containing 2 per cent of ethylene dichloride was applied. It is apparent from these results that none of the insecticides used in the oil had any material effect on the development of the tip kernels.

EFFECT OF TIME OF APPLICATION.—Ears in 29 fields of sweet corn grown for seed in Canyon County, Idaho, were tagged on the first day of silk exposure. Fifty of these ears in each field were given a single treatment with white oil of 125/135 seconds viscosity containing 0.2 per cent of pyrethrins at a dosage of 0.75 cc. per ear, 10 of the ears in each field being treated each day from the sixth to the tenth day after silking. Records of the average length of the undeveloped tips in treated and untreated ears in each field are given in table 3. The records show that in six fields (Nos. 1, 6, 8, 20, 23, and 24) oiling on the sixth day was too soon after silking, and in one field (No. 23) oiling on the seventh day was too soon, as indicated by the average length of the undeveloped tips. With these exceptions there was no correlation between the day of oiling and an increase in the length of the undeveloped tips. In 8 fields there was no apparent increase in the length of undeveloped tips in treated ears as compared with untreated ears, in 9 fields the undeveloped tips of oiled ears averaged less than 0.25 inch longer than those of untreated ears, in 7 fields the average increase in length of

undeveloped tips due to oiling was between 0.25 and 0.50 inch, and in only 5 of the 29 fields did this increase average more than 0.50 inch. The average length of the undeveloped tips in all 1410 ears oiled in this experiment having tips that were not injured by earworms and, consequently, measurable, was only 0.1 inch greater than the average for 290 untreated ears.

DISCUSSION.—In most of the fields of sweetcorn observed by the writer in different parts of the country some ears were characterized by undeveloped kernels for various distances below the tip of the cob. This condition is so universal that it may be considered characteristic of commercial sweet corn. The length of the undeveloped tips may be increased, however, by the application of oil for earworm control because of (1) its inhibiting effect on the development of immature kernels when the oil reaches them, and (2) its interference with the pollination of tip kernels that put forth their silks during a secondary growth of the cob some time after exposure of the main silk mass, often after the first-exposed silks have become brown. The results of the investigation reported herein show that when oil is applied after pollination is complete, *i.e.*, not earlier than 1 week after silk exposure, the frequency with which the oil reaches the tip kernels varies inversely with the length of the husk extension beyond the tip of the cob and directly with the dosage of oil applied per ear. In most sweet corn varieties observed by the writer the husk extension beyond the tips of the cobs is variable in length, and this variation apparently is as great in hybrids as in open-pollinated varieties. The data reported in this paper indicate that the most desirable ears from the standpoint of application of the mineral-oil treatment would be those in which the husk extension is uniform and about 2 to 3 inches beyond the tip of the cob. The data also indicate that applications of 0.5 cc. of oil to such ears would result in negligible interference with kernel development at the ear tips, because this dosage would be retained in the silks and little if any of it would reach the kernels. Probably a dosage of 0.5 cc. of oil or oil containing an insecticide would be safer for use in most sweet corn than the usually recommended dosage of 0.75 cc. per ear. It is likely that the smaller dosage would result in nearly as high a rate of control as the larger, but this subject needs further investigation.

SUMMARY.—In commercial and experimental use of the mineral-oil treatment for earworm control in sweet corn an increase in the length of undeveloped tips of treated ears was the result of (1) inhibition of the development of immature kernels if the oil reached them, and (2) interference with pollination if a secondary growth of the cob occurred, as evidenced by late appearance of a tuft of fresh silk from the tip kernels. Whether oil did or did not reach the kernels was determined by the length of the husk extension and the dosage of oil. No significant difference was found between the increase in length of undeveloped tips caused by the oil alone and by oil containing insecticides. Oil applied at a dosage of 0.5 cc. to ears having a husk extension of at least 2 inches caused negligible increases in the length of the undeveloped tips, but the length of the undeveloped tip was increased when the husk extension was less or the dosage was greater. The evidence showed that it was safer to begin the treatment on the seventh day rather than the sixth day after silk exposure. The average increase in the length of undeveloped tips caused by commercial or experimental oiling of Golden Cross Bantam sweet corn was not more than 0.4 inch per ear. In 7-inch ear this represents a loss of only about 5 per cent of the kernels. This loss is thought to be of very minor importance, as compared with the great improvement in quality, quantity, and value of the crop resulting from the proper application of the treatment.—7-24-44.

DR. F. C. BISHOPP TO LECTURE IN NEW YORK

Dr. F. C. Bishopp, of the Bureau of Entomology and Plant Quarantine has been chosen to deliver the Hermann M. Biggs Memorial Lecture, presented annually in Hosack Hall at the New York Academy of Medicine under the auspices of the Committee on Public Health Relations.

The date of the lecture will be April 5, 1945 and Dr. Bishopp's subject is "The Medical and Public Health Importance of DDT."

The Effect of the War on Truck Crop Insect Control in California[1]

W. Harry Lange, Jr., *California Agricultural Experiment Station*

Dr. P. N. Annand (1944) ably expressed the effect of the war on our research programs in relation to agricultural crops in his presidential address before the fifty-fifth annual meeting of the American Association of Economic Entomologists when he said, "Research has been aimed at immediate objectives, attention to the long-time aspects being reduced to that necessary to prevent large losses in lines of work which owe their value to continuity over a period of years."

The agricultural entomologist working on commercial crops is made very much aware of the necessity for making immediate recommendations, often for insects for which no entirely satisfactory methods have yet been found. To make these recommendations he must apply a number of materials, often to large areas, trying to ascertain first which materials will be available in sufficient quantities to adequately take care of the immediate picture, and not necessarily those which he may think would be more effective. This type of research often yields very interesting results and satisfies the large grower in that he sees immediate action. On the other hand, it has the drawback of waste, and in certain instances the high price of protection may not be applicable to post-war conditions.

In addition to the immediate nature of research work on truck crops during war conditions the entomologist is also confronted by shortages of materials which may come up unexpectedly, such as the recent shortage of nicotine and he must have alternative methods ready which may not be entirely satisfactory, but will give an economic control from the grower's standpoint.

The insect problems of the larger acreages of commercial truck crops do not differ from those of small truck farms for the most part, but they do involve problems of application of the materials in an economic manner, timing of application to correspond with standard irrigation practices, and the need for better dusters and sprayers. For example, a field of 100 acres of cabbage may take a period of from 10 to 20 days to irrigate which means that frequent applications by ground machines may be impossible. The small truck crop grower can afford to dust by hand and often can get into his fields soon after irrigating.

Since 1942 research work of an immediate nature has been carried out in the Salinas Valley and environs on the larger acreages of commercial vegetable crops and certain field crops. Space does not permit a discussion of all the truck crop insect problems in this area, but mention is made here of some of the more important insects together with recent developments in their control.

Wireworms.—Wireworms of the genus *Limonius*, *L. californicus* (Mann.), *L. canus* Lec., and *L. infuscatus* Mots., continue to be one of the more pressing problems on irrigated lands as is true in many other California localities. The use of granulated calcium cyanide drilled at the rate of 100 pounds to the acre into a trap crop of beans or in certain instances into seedling plants has given kills of from 68 to 85 per cent. The material is usually applied through a lettuce planter using a deeper shoe, and in lighter soils a ring and round roller are used to seal the surface of the ground. Fertilizer drills are also used but are often difficult to regulate to the required dosage. This method has limitations in that often many wireworms are not attracted to the bait crop. For this reason several applications may be necessary.

Dichlorethyl ether[2] has been used during 1943 and 1944 on commercial acreages of lettuce chiefly as a repellent, using 600 gallons of emulsion to the acre of a 0.5 per cent strength. This material is applied through a commercial spray rig, removing the nozzles and whirl plates and running the liquid directly on small lettuce seedlings before thinning. This amount of ma-

[1] Paper presented on the program of the Pacific Slope Branch, 1944.

[2] Commercial preparations containing approximately 4 per cent of a soluble emulsifier.

terial is of value only if applied prior to thinning and prior to severe damage, the value being considered chiefly as one of repellency.

The new DD mixture 1-2 dichloropropane and 1-3 dichloropropylene was first mentioned by Carter (1943) for control of the root knot nematode and again by Carter (1944) for certain ground beetle larvae in the soil around the roots of nursery stock. Stone (1944) using this material in emulsion form found it to be toxic to larvae of the sugar-beet wireworm, *Limonius californicus* (Mann.). In the Salinas Valley in field experiments conducted during 1943 and 1944, the application of this mixture by the continuous flow method at an 8-inch depth, applications 15 to 18 inches apart, using crude material in undiluted form, at dosages of from 200 to 600 pounds per acre, with and without the use of liquid ammonia, gave noticeable increases in lettuce yields in a badly infested field and at 400 lb. or more per acre, substantially reduced the wireworm population. These results will be presented in a separate paper.

CABBAGE APHID AND CATERPILLARS.—The increased need of cabbage for dehydration resulted in an increase of cabbage acreages. This led to extensive aphid and caterpillar damage. During 1943 (Lange 1944) a free nicotine and cryolite or calcium arsenate dust was widely used with good results in most cases. The nicotine alkaloid content of these dusts varied from 2.5 to 3 per cent (made from 80, 95, or 99 per cent alkaloid nicotine) and usually contained neutral carriers such as *Frianite*, talc, diatomaceous earth or pyrophyllite. It was found that 30 per cent cryolite was not too effective on larger caterpillars of the imported cabbage worm. A rotenone-free nicotine dust containing 0.5 per cent rotenone and 3 per cent nicotine as alkaloid was used on older cabbage at from 40 to 50 pounds per acre with excellent results. The 0.5 per cent strength gave approximately 85 per cent kill of imported cabbage worm larvae in from 7 to 10 days after treatment. The use of *Velsicol 60* in cabbage dusts was found to increase the kill of caterpillars slightly when used with rotenone, and several other materials including crude DD and *Crystox* were not effective. The use of dichlorethyl ether with free nicotine did not materially add to its effectiveness for cabbage caterpillars, but at a 2 per cent nicotine alkaloid strength increased the kill of cabbage aphids by approximately 10 per cent.

It was found that a 3 per cent alkaloid dust was necessary to obtain adequate control of cabbage aphids by ground machines. The addition of 4 per cent alkaloid to dusts was started early in 1944 and this dust was more effective for plane application. The best results with free nicotine dusts were obtained when moisture was present on the plants and the dusts remained in the rows long enough to get adequate penetration into the heads. The shortage of nicotine makes it necessary to stress conservation in the use of nicotine dusts and the lowering of the alkaloid content to a level of economic control.

ROOT APHIDS.—The sugar beet aphid, *Prociphilus betae* Doane, continues to be a problem on lettuce especially during August and September, where it occurs on the roots. This aphid apparently has no sexual cycle in central California but migrates from docks, sugar beets, and other weeds to lettuce and from lettuce to lettuce. It is often confused with several other aphids including *Pemphigus populitransversus* Riley and *Thecabius populimonilis* (Riley) which form galls on cottonwoods in this region. Chemical treatments so far have not been effective. Adequate irrigation, fertilization, and cultivation often assist in averting serious injury.

MAGGOTS.—In cabbage seed beds, a 0.5 per cent emulsion of dichlorethyl ether was found effective in stopping further injury of the cabbage maggot, *Hylemya brassicae* (Bouché), when used at the rate of 0.5 pint to the lineal foot of row, applied by hand compressed air sprayers or larger spray rigs (Lange 1943).

The seed-corn maggot, *Hylemya ciliorura* (Rond.), is becoming a serious pest of onions and other plants in the seedling stage. During 1944 approximately 90 acres of onions were lost in the Salinas Valley. The maggots are also severe on spinach, alfalfa, and bean seedlings and are capable of boring inside the larger spinach stems and in the hearts of celery. It was found that a 0.25 per cent solution of dichlorethyl ether applied at the rate of 900 gallons per acre (3-row planting to a bed) did not affect onion seedlings and adequately checked the damage.

Onion maggots, *Hylemya antiqua* (Mg.)

were severe only in small truck crop areas. A 0.5 per cent strength of dichlorethyl ether was effective on this maggot, but should not be applied to small seedlings at this strength as some injury may occur.

GARDEN CENTIPEDE.—Garden centipede damage to lettuce, beans, sugar beets and cauliflower seedlings has been increasing during the last two years. Dichlorethyl ether as mentioned for wireworms has been used with some success as a repellent for small lettuce seedlings before thinning. This method at the 600 gallon per acre dosage is considered a temporary treatment and one which could be used only on high priced land such as occurs in the Salinas Valley. The cost of the treatment and material has varied from $17 to $20 per acre.

ONION THRIPS ON ONIONS.[1]—There cent paper by Ewart *et al.* (1944) brings to our attention the problem of onion thrips on onions. These investigators indicate that it is advisable to make from 5 to 6 applications of tartar emetic sugar-water (2 pounds–4 pounds–100 gallons) spray at about 6 day intervals beginning when the onions are from 4 to 6 inches high. Our poor results with this material in California may be due to the fact that little control is usually attempted until the thrips have reached high population levels. In the Salinas Valley during 1942 a spray of tartar emetic, 5 lbs., *Karo* syrup, 15 lbs., and water, 100 gals., applied once at the rate of 200 gallons per acre with 400 pounds pressure after thrips were present in considerable numbers gave a 48 per cent reduction as compared to less than 1 per cent for nicotine bentonite (3 pounds–100 gallons), 46 per cent for nicotine sulfate and oil (1 pint–1 gallon, light medium) and 50 per cent reduction for a mixture of cryolite 3 lbs., rotenone, 1 pint of 5 per cent and pyrethrum, 1 pint of 2 per cent.

Campbell & Persing[2] during 1943 found that a nicotine sulfate-sugar-*Vatsol OTC*-water (1 quart–4 pounds–1.5 pounds–100 gallons water) was the best formula in field tests.

THRIPS ON BEANS.—On beans *Frankliniella helianthi* Mlt. has been severe on bush types during July. A free nicotine-cryolite mixture applied as a dust (of the same type used on cabbage) was found to give a satisfactory reduction of populations when applied at from 35 to 40 pounds to the acre. This same species also occurred on peas.

During the 1942–44 war period several new additions to our economic list were recorded which are mentioned because of their possible damage in the future.

Autographa egena Gn., a bean semilooper, seriously damaged pole beans in the Salinas Valley during October, 1943.

The Japanese onion aphid, *Micromyzus formosanus* Tak., was found on stored Australian brown onions, and on field planted garlic during May, 1944.

The rusty-banded aphid, *Aphis ferruginea-striata* Essig, which occurs on celery and docks was found to seriously damage carrots. It occurs in large colonies about the crowns.

The bean root aphid, *Trifidaphis radicicola* (Essig), is not a new offender, but was found infesting field planted small white beans during the fall of 1943.

In conclusion it is seen that the effect of the war on truck crop insect control problems in California is not materially different from other fields of entomology—an immediate need must be met, but the very meeting of this need together with our accelerated advance of knowledge in all scientific fields will set the stage for a firm postwar research program.—7-24-44.

[1] Since this paper was submitted two applications of a DDT spray containing 0.15 per cent DDT, used at the rate of 190 gallons per acre, gave a better control of nymphs than a number of recommended treatments, including those referred to in this section.

[2] Campbell, Roy E. and C. O. Persing, 1943, Experiments in 1943 for control of the onion thrips in southern California Mimeo. 1 page.

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Insecticidal Properties of Mamey and Other Plants in Puerto Rico

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With view to finding possible new sources of plant insecticides to relieve shortages caused by the War, above-ground portions of plants other than *Derris* and *Lonchocarpus* growing in Puerto Rico were subjected to rapid exploratory tests for insecticidal properties against locally available insects. The most promising of those species collected by Moore (1938) for preliminary tests by the Bureau of Entomology and Plant Quarantine were considered first, other promising or closely related species being selected later with the cooperation of Dr. Moore and Milton Cobin of this station. While this work is still in progress, it seems desirable to record briefly the results secured thus far so that investigators elsewhere may have the opportunity to make trials under other conditions.

Preparation of the plant material consisted in air-drying in the shade at room temperature and grinding through a 0.5-mm. sieve in a *No. 1 Wiley Mill*. The tests followed closely those employed by Swingle (1943). Pieces of host leaves dusted heavily by rolling in the material to be tested were placed in pairs in 3.5-inch petri dishes with five field-collected or reared insects of the same species and stage of development. Each test was replicated five times. Untreated host leaves handled similarly served as controls for each set of tests on a given day or for each lot of insects. Counts of living and dead and notes on the extent of feeding were made at the end of 48 hours. The percentage reduction in the number of living insects in the treated dishes below that in the controls was taken as the percentage toxicity of the material.

Tested against three to six species of insects, the following plant parts showed 40 percent or less toxicity with much feeding: *Calophyllum inophyllum* L. seeds, hulls; *Carapa guianensis* Aubl. leaves, petioles, bark, wood; *Cassia nodosa* Hamilt., seeds, leaflets, petioles, bark; *Entada polystachya* (L.) DeC., leaflets, petioles, stems; *Enterolobium cyclocarpum* (Jacq.) Griseb. leaflets, petioles, bark, wood; *Gliricidia sepium* (Jacq.) Kunth., leaves, petioles, bark; *Indigofera endecaphylla* Jacq. seeds, leaves, stems; *Mammea americana* L. (mamey) seed hulls, immature fruits; and *Pachyrhizus erosus* (L.) Urban var. A. pods.

Up to 95.9 percent toxicity, mostly with little or no feeding, was shown by

Table 1.—Toxicity of Mammea americana and Pachyrhizus erosus.

PLANT PARTS	*Corotoma ruficornis*, ADULTS	*Diaphania hyalinata*, LARVAE	*Laphygma frugiperda*, LARVAE	*Plutella maculipennis*, LARVAE
		Mammea americana		
Bark	4.0	54.2	16.0	56.0
Leaves	0	75.0	59.1	34.8
Mature seeds	95.9[1]	88.6[2]	90.5[3]	91.5[1]
Hulls	0	4.2	4.0	0
Mature Seeds 67% Hulls 33%[4]	92.0	79.2	84.0	76.0
		Pachyrhizus erosus var. A		
		—P.I. 88365—		
Pods	0	4.2	0	4.0
Seeds 50%, pods 50%[5]	0	80.0	41.7	72.0
		—C43-23—		
Pods	0	4.0	— 8.7	— 4.2
Seeds 50%, pods 50%[5]	0	84.0	40.0	56.5
		—B. of E & P.Q.-Mexico—		
Pods	0	4.8	0	—
Seeds 50%, pods 50%[5]	0	95.2	76.0	69.6

[1] Weighted average of 2 tests.
[2] Weighted average of 3 tests.
[3] Weighted average of 4 tests.
[4] This addition during grinding improved the workability of the dust.
[5] These pods were added in grinding to improve physical condition of the dust, but it was still somewhat oily.

parts of some of the other plants under investigation. The most outstanding have been the mature seeds of mamey and of some introductions of the yam bean, *Pachyrhizus erosus* (L.) Urban, var. A. The toxicity of these and other parts of these two plants to four insects is given in table 1.

Other than mamey seed hulls and yam bean pods, which were practically inert, mamey bark and yam beans mixed with pods were the only materials in this group that permitted any feeding and then only in those tests involving adults of *Cerotoma ruficornis* (Oliv.) and larvae of the fall armyworm, *Laphygma frugiperda* (A. & S.) From the tests made, mamey bark seems to have feeble insecticidal properties. The better results secured with powdered mamey leaves, especially on the melonworm, *Diaphania hyalinata* (L.) are of interest in Puerto Rico in view of the long-established and effective use of the whole leaves as a wrapping about newly set plants to prevent insect attack at or below the ground line. The mature seeds of mamey were highly toxic, both the undiluted and the 67-per cent dusts being superior to the 50-per cent dusts of all three introductions of the yam bean except in some tests with the melonworm. It is interesting to note that, whereas the mamy seed dusts killed over 90 per cent of the adults of *C. ruficornis*, mamey leaves and hulls and all the yam-bean dusts were inert to this insect.

The action of mamey seeds seems to be that of a contact insecticide. When placed out of contact with larvae confined for 2 days on untreated host leaves in petri dishes, the undiluted dust gave negative results as a fumigant on the melonworm and the fall armyworm. However, when dusted heavily on larvae similarly confined, it was 100[1] per cent toxic to the melonworm, 88 per cent to the fall armyworm, and 48 per cent to the diamondback moth, *Plutella maculipennis* (Curt.); untreated larvae on untreated foliage in other dishes served as controls. Applied as a spray at 8 lb. in 100 gal. water without a spreading agent, the same material killed 44.1 per cent of *Myzus persicae* (Sulz.)[1] on *Brassica perveridis* and 43.4 per cent of *Macrosiphum sonchi* (L.), on *Senecio confusus* Britton, in 2 days and did not injure the plants; the untreated aphids were sprayed with water only. N. F. McIndoe, U. S. Bureau of Entomology and Plant Quarantine, states[2] that Tattersfield *et al.* (1926) found some extracts of this plant from the West Indies not to be sufficiently toxic to *Aphis rumicis* L. to warrant further investigation, but that Tattersfield & Gimingham (1932) found extracts of the roots, shoots, and branches from Trinidad to be slightly toxic to this insect.

Under field conditions the diluted mamey-seed dust produced good control of larvae of the diamondback moth. Applied with a hand dust gun, at an average rate of 8.6 grams per plant, on a small plot of moderately infested cabbage, this material gave a kill of 80 per cent in 4 days. With dew on the plants at the time of application the dust adhered well without rain and no injury to the plants was noted. The dust deposit secured was still toxic after 4 days of exposure to sun, wind, and dew. Sprayed on heavily infested cauliflower at the rate of 8 lb. per 100 gal. water plus 6 oz. *Grasselli Spreader-Sticker* the undiluted powder produced in 4 days 67.9 per cent control of the diamondback moth and 73.6 per cent of the few larvae of *Ascia monuste* (L.) present. In comparison 40-per cent nicotine sulfate 1 to 800 plus the same amount of spreader-sticker gave 73.5 per cent and 87.5 per cent control respectively of the same insects. There was no statistically significant difference between the control of the diamondback moth by mamey and that by nicotine sulfate.

Preliminary tests of a kerosene extract of finely ground mamey seeds as a household insecticide indicated toxicity to cockroaches, mostly *Periplaneta americana* (L.) and *Blatella germanica* (L.), flies (undetermined), ants, principally *Prenolepis longicornis* (Latr., and mosquitoes (undetermined). The extract was made by soaking 8 oz. of the powder for 24 hours, with intermittent agitation, in 1 qt. of kerosene at room temperature and filtering. Applied with a small hand sprayer in the open, this extract appeared to act slowly but permitted little recovery.

That the active principle in mature mamey seeds is ether-soluble was shown by laboratory tests of the residue remain-

[1] Determined by P. W. Mason, U.S.D.A., Bureau of Entomology and Plant Quarantine.

[2] In correspondence.

ing after extraction in a Soxhlet extractor.[1] This residue was not toxic to the melonworm, the fall armyworm, or the larvae of the diamondback moth, whereas the unextracted material tested simultaneously produced from 79 to 96 per cent control of the same insects. Further study of various extracts is in progress.

The mamey, a tree of the family Gutiferae growing to 60 feet in height, is considered by Popenoe (1920) to be indigenous to the West Indies and the northern part of South America; it also occurs in other parts of tropical America and is successfully cultivated in southern Florida. In Puerto Rico there are large numbers of thrifty trees, particularly on lateritic soils, that produce, in 2 crops each year, from 300 to 400 of the nearly round fruits 4 to 6 inches in diameter. The firm yellow flesh, commonly eaten fresh or as preserve, encloses from 1 to 4 large seeds averaging about 1.5 ounces each in weight including a heavy, rough hull. About 75 per cent of the fresh seed is a creamy white kernel, and this is the insecticidally active part. When wilted by drying, the kernel retains all of its gummy sap during preparation for grinding.

Very few insects, none of any importance, attack mamey in Puerto Rico. Wolcott (1936) records the occurrence of several scales and other homopterous insects on the leaves and branches, a beetle on the leaves, and the rice weevil on the seeds. The writer has found the larvae of the phycitid *Myelois notatalis* (Wlkr.)[2] infesting the region just inside the hull of about 1 per cent of the seeds that have weathered. Since the kernels of such seeds are usually blackened and in various stages of disintegration, it is believed the attack of this insect in secondary. No insect infestation has been found in seeds gathered and separated from the pulp soon after the fruit has fallen.

The literature contains few references to the use of the products of mamey as insecticides. According to the U. S. Department of Agriculture (1922), quoting F. W. Goding, M. D., in Ecuador, the sap from the bark is extensively used for killing chigoes and lice, a decoction of the seeds for mange and sheep ticks, and a cerate for many kinds of insects. Roig y Mesa (1928) says that in Cuba the resinous gum from the tree is used for skin diseases caused by "parasites." With the relatively high toxicity to phytophagous insects secured in the present work, the ease of preparation and application and the availability of the supply from trees already in bearing make mamey seeds a convenient source of a promising insecticidal material.—9-14-44.

[1] This extraction was made by Merriam A. Jones, chemist, Federal Experiment Station, U. S. Dept. Agriculture, Mayaguez, P.R.

[2] Determined by Carl Henrich, Bureau of Entomology and Plant Quarantine.

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Dr. W. W. HENDERSON

Dr. William Williams Henderson (1879–1944) died on October 24, 1944, at Logan, Utah. Dr. Henderson was, for a period of 21 years, Professor of Zoology and Entomology at the Utah State Agricultural College and, at the same time, Entomologist of the Agricultural Experiment Station.

Physiological Behavior and Geography in Control of the Alfalfa Butterfly

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The application of the biological principles of heredity and development to wild populations is one of the natural outgrowths of the integration of science. The application of these same principles for the economic welfare of mankind in the control of insect pests and of human disease organisms will assume increasing importance as the value of these principles become more generally acknowledged.

Several important biological phenomena were observed in the course of genetic and physiologic work on the alfalfa and clover butterflies *Colias chrysotheme*, (Hovanitz 1943a). It is the purpose of this paper to illustrate the value of such work in the elucidation of some economic problems and to show how such knowledge aids in the application of natural control measures.

GEOGRAPHICAL RELATIONS.—*Colias eurytheme* is a serious agricultural pest by virtue of the enormous abundance of its larvae in alfalfa fields. At the present time the form ranges from the southern part of Canada across the continent from the Pacific to the Atlantic and south through the entire uplands of Mexico (Hovanitz 1944a). However, only in the interior valleys of California and Arizona does it appear to be sufficiently abundant to be called a pest.

Before man brought alfalfa from the Mediterranean and Asia Minor regions of the old world to America, *eurytheme* apparently fed upon various leguminous plants. The primary of these were probably *Vicia*, *Astragalus* and some species of *Trifolium* using judgment based upon present day breeding habits under natural conditions and upon the old literature. It is supposed that the first alfalfa to become established in North America was in California where the environmental conditions were most like its home in Europe and also its newly adopted home in Chile. In the vicinity of the latter country, a butterfly almost identical with that of eurytheme occupies a place similar in economic importance and in biological relations to *Colias eurytheme* in North America. This is *C. lesbia*. There is little likelihood that these two species had a similar origin, though the arguments are too long to present here. We will assume that *C. eurytheme* is a species endemic to North America and that its earliest known home in western North America represents the area from which it later spread by the influence of man. Then we can look at the conditions which are responsible for its expansion into other regions.

BIOLOGICAL RELATIONS WITH THE ENVIRONMENT.—Where *eurytheme* lives in the wild condition at the present time, the species is generally distributed everywhere and is widely scattered with respect to individuals. In this it is very different from that of many other butterflies. *Melitaea*, *Argynnis* and other groups are found only in certain isolated places but there they are usually found in very large numbers. What are the factors which lead to this difference in behavior between the species of butterflies and how are these correlated with the success of the species as an agricultural pest?

Three factors stand out clearly. First, the wild food plants of this species are small in size and are usually widely scattered over the terrain. This leads to the impossibility of many larvae having the food available for complete development upon the same relatively isolated plant. The immature individuals, under wild conditions then, are growing at widely separated intervals.

Second, the female Colias lays but a single egg at a given place, always taking flight before laying another. This is a characteristic typical of the entire group and is true for individuals in the laboratory cages as well as in the wild. In the cages many eggs are laid upon the same leaf because of the limited number of leaves in a cage but there is present a period of flight between the laying of each. Under natural conditions, this method of placing the eggs scatters them over a tremendous territory. Melitaea butterflies on the other hand lay their eggs in a few very large batches without flying away

from the colony in which they were born.

Third, the females of *Colias eurytheme* make very long flights. They will be seen over the hills and mountains flying very swiftly, stopping occasionally here and there to investigate a plant, possibly laying an egg if it should be the correct variety. In locations where a good crop of the proper legume is present often many females will tend to concentrate in large numbers.

The presence of a growth of alfalfa along the path of these females is sufficient inducement to cause them to stop. It is impossible to go into any physicochemical detail on the reason why alfalfa, of many other legumes, is attractive to *Colias eurytheme*, or why soybeans are attractive to a Japanese *Colias*, or why red clover is attractive to the yellow race of *C. chrysotheme*. This will have to await refinements of knowledge on chemical specificity or attractions. The mere fact that this is true must suffice for the present time. Just how far in the matter of spatial distance this attraction exists is also not known. It is possible that there is contact attraction only, in which case it is only by chance that the proper plant is located. Yet, females in swift flight have been seen to hesitate over various legumes, completely ignoring other plants.

The migratory habit of *Colias eurytheme* females renders it extremely unlikely that many more than a few eggs will be laid upon any plant by any one individual. Consequently it is essential, in order for a field to be heavily infested, that there be a large source of females in the immediate vicinity. The field data seems to substantiate this well. The economic destructiveness of the *Colias* is present only in regions where many alfalfa fields are in close proximity, one to the other. Completely isolated fields never have more than a few individual butterflies.

Along with observations made on the frequencies of white versus orange females in populations, it was observed that certain kinds of fields would harbor differing frequencies of males and females. For the purpose in which we were interested, it was desirable to locate those places where females were most abundant. In very recently cut fields it was found that the adults were nearly all females whereas in the fields with alfalfa one half to full grown they were nearly all males. Such a condition was found to be universally true throughout the alfalfa growing districts of California.

In one particularly large field in the vicinity of Bakersfield this pattern was easily observed. Ranchers with fields several hundred feet wide and a half mile or more long would cut a field crosswise starting at one end. With sections set apart by irrigation ditches, one section would be cut at a time. After a time interval in which the alfalfa of one section was dried and baled, the next section would be cut. The result was that each section was in a different stage of growth as shown in the diagram (Fig. 1).

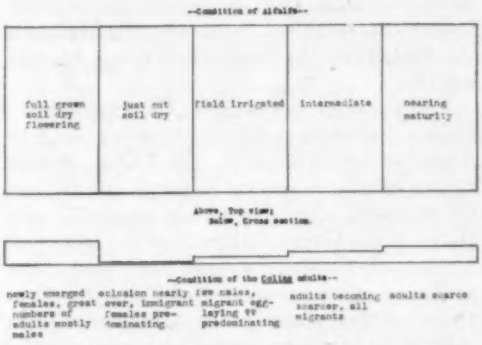
--Condition of alfalfa--
full grown soil dry flowering
just cut soil dry
field irrigated
intermediate
nearing maturity
Above, Top view;
Below, Cross section.
--Condition of the Colias adults--
newly emerged females, great numbers of adults mostly males
eclosion nearly over, immigrant females predominating
few males, migrant egg-laying ♀♀ predominating
adults becoming scarcer, all migrants
adults scarce

FIG. 1.—Diagram showing characteristics of Colias population and a very long alfalfa field in various stages of cutting and growth to illustrate the relation between alfalfa cutting and Colias breeding. Semi-diagrammatic.

Now the females concentrate laying their eggs in the section with very freshly grown leaves—the section just recently cut. Consequently most of the larval crop in a given field or section of a field is of the same age and will grow to maturity at the same time. At a constant temperature of 25° C. a three week period is sufficient for the growing from egg to adult. Conditions in the interior valleys of California and Arizona are sufficiently equal to this to bring the natural life cycle up to three to four weeks in the summer time. Also under these conditions the alfalfa will be ready for cutting in about a month's time. Where conditions such as these are present the Colias population is enabled to build up to enormous numbers as the adults will have emerged from the pupal case before cutting and baling.

It is imperative then that females be

available for egg laying at the time of cutting in order that the next generation will be able to coincide with the next phase of alfalfa cropping. These adults will primarily come from nearby fields which are in the proper phase. Eggs that are laid too late upon the newly cut field will have little chance to reach maturity owing to the later destruction of the pupae and larvae. The pupae are usually attached to the plant stems at about the central third and thus are on the cut portion. Some few remain on the lower stubs and are not destroyed.

Under the environmental conditions early in the season or late in the season when the temperature is lower, it seems that the growth rate of the butterfly may be slower than that of the alfalfa so that the alfalfa is cut at intervals oftener than the broods of the butterflies come to maturity.

DESTRUCTIVENESS AND GEOGRAPHY.—*Colias eurytheme* does not occur in epidemic proportions in all those places where alfalfa is grown in large quantities. Of western alfalfa growing regions, only those of the Great Valley and the Imperial Valley of California and the Gila river valley of Arizona seem to be disturbed in the economic sense. Since, however, alfalfa is grown in large quantities also in the coastal valleys of California, in the Great Basin and the Rocky Mountain valleys as well as by far the greater quantity in the middle western plains and the Lake States with little economic difficulty from this source, it would be interesting to discover the reason, climatic or otherwise, accounting for such a phenomenon.

The Pacific Coast: In the Willamette Valley of Oregon and the Coast Range Valleys of California, the lower temperatures and weaker and shorter sunshine hours of the summertime[1] as compared with the Great Valley apparently do not allow *Colias* to become abundant nor allow its broods to coincide with alfalfa cropping. The effect of direct sunshine on the speed of larval growth is a factor seldom given sufficient weight in considering growth rate. While the coastal temperatures are never actually as low as those inland (nor as high either), the effect of more sunshine hours and direct heat absorption by the larvae in the inland areas in the summer would cause a more rapid growth rate. This may actually account for some otherwise inconsistencies in the story of temperature as a controlling factor in the destructiveness of the alfalfa butterfly in California. The inland Great Valley populations of Colias become very destructive while those of the coastal San Fernando Valley of southern California do not. The average temperatures of the two places are about the same; from this standpoint an equal destructive value is to be expected. But the San Fernando Valley has a more coastal climate, a greater period of fogginess both daily and seasonally than the more inland, though farther north, Great Valley. The lesser extent in acreage of the fields of the former, too, would make it more difficult to build up a large population in the period of months seasonally available.

The Lower Colorado River Basin: This area, including the Coachella Valley, the Imperial Valley and the Yuma Valley parts of the Gulf of Colorado trough, is the hottest place in which *Colias eurytheme* exists. It is hotter in the summer time than our laboratory experiments indicate that this species can exist without sterility. Yet it is an area in which the species at times becomes an agricultural pest of tremendous proportions. The heat of the area is, however, partly a daily phenomenon produced by the direct solar radiation and largely lost at night. The area is exceedingly arid, of negligible rainfall, of low humidity and of very high percentage of cloudless sky days. It is isolated from the effects of the coastal fogs.

The breeding period of the *Colias* populations here takes place all year in considerable numbers. In the winter, however, it is rarely warm enough for a rapidly growing population. In the mid summer and fall, depending upon yearly differences, it is too hot for population growth though there are considerable individuals in existence. It was observed during this season that the adult butterflies are most active between the hours 7 to 10 A.M. and 6 to 7 P.M. as contrasted with 9 A.M. to 4 P.M. in the coastal or more northern areas. During the midday individuals were rarely seen flying, a phenomenon very unusual for a non-tropical butterfly. Large numbers were observed at rest in

[1] Owing to fogginess or cloudiness near the coast. The Great Valley and other inland areas of California have the lowest degree of summer cloudiness of any area in North America (Brooks 1936). For a general discussion of climatic factors in the region see Michelbacher & Leighly (1940).

the shade of alfalfa bales still in the fields and it was only necessary to observe the resting adults in order to count them. The sunflowers growing as weeds along the drainage and irrigation ditches and roads also constituted a haven for protection against the sun. By beating the plants, some could be activated, but in flight they made immediately for the nearest shade.

This observation is an important one since in the fields of this area, weeds and especially sunflowers provide probably the only refuge the adults have against desiccation and complete sterilization in the summertime. It is clear that they are living at the limit of their temperature tolerance and may be eliminated easiest by removing the means of protection against an excess of heat. Another point may be mentioned here which would indicate the seriousness of the weed and sunflower problem and would indicate their elimination throughout the alfalfa growing regions of the west.

Colias is clearly only a pest by virtue of its tremendous numbers. If these numbers were reduced even without eliminating the species completely, great value would result. Laboratory breeding has indicated that *Colias eurytheme* females are capable of laying 50 eggs within a day or two of adult emergence and copulation without taking any food as an adult. They will then lay no more and die in a day or two depending upon the temperature and humidity. The lower the humidity and the higher the temperature, the shorter the length of life without food. But with a meal of honey or nectar in flowers once per day, each female is capable of laying this same amount of eggs each day for one or two weeks totaling more than 1000 eggs. It is clear that if a food source such as weed flowers along the margins of the fields were eliminated, the next Colias generation would be greatly reduced. Equally important would be the cutting of the alfalfa before flowering since the nectar produced by these plants, too, is preferred by the adults. No loss would be incurred from this since alfalfa does not flower until full grown anyway.

The Mississippi Valley and Great Lakes Region: Colias eurytheme in the eastern portions of this region is a recent migrant (Hovanitz 1944a). Nevertheless, if environmental conditions were at optimum one should expect the species to become exceedingly abundant, in the same degree that the alfalfa has become abundant. But the evidence is that it has not done so despite the great expanse of area in which the plant is grown.

What physiological characteristics have prevented this abundant increase so far? Several possibilities may be cited. The lack of a definite diapause such as possessed by the clover race (*Colias philodice* etc.) would be a decided disadvantage in the territory where the winters are below freezing for any length of time. The great reduction in population during the winter months would probably be sufficient to prevent enough increase during the growing season of two or three generations so that the insect would not be of agricultural importance. It is clear that this factor is of major importance in controlling population not only in the orange race (*C. eurytheme*) but also in the yellow race. It is a common phenomenon that the first generation of the year consists always of a few individuals, with an increase in numbers with each successive one until the following winter. Clark (Hovanitz 1944a) presents evidence to indicate that several years of selection or of population "build-up" was necessary before *Colias eurytheme* survived the winters in the vicinity of Washington, D. C. There is always the possibility of genetic acclimatization (in this case, natural selection of favorable genetic material) taking place as the race increases its natural geographical distribution, in much the same way as physiological strains of alfalfa itself had to be selected before its survival in the eastern United States was economically satisfactory. Such physiological counterparts within the orange race seem indicated on the basis of physiological studies on the color patterns.

The genetic evidence indicates that the factor controlling the diapause is not separable from that controlling the food preference and usually the color difference. But it is always to be expected that minor factors tending to produce similar results but in different ways are present, to be selected for by the environment.

GENETIC VARIATION IN POPULATIONS. —The difficulty of applying physiological data obtained upon a strain of insect occurring in one place to another of identical appearance occurring in another place (or to even different individuals in the same

place) is shown clearly by the Colias in California.

The details of the varying frequency of a dominant gene controlling a physiological color character has been published elsewhere (Hovanitz 1944c). It has been shown that this gene, besides giving a white color to the females carrying it, gives those individuals a more rapid developing rate so that the white individuals emerge as adults in an alfalfa field earlier than the orange. In any field where the coincidence of Colias broods and alfalfa cropping is nearly the same so that a large proportion of the slower growing individuals are destroyed by the cutting and baling process, the rancher selects more of the white than the orange individuals. Under natural conditions, too, such a selection would take place since the faster development rate of the white females would more equal the males in time of eclosion. That all individuals are not white after a period of time seems to be due to a lethal or semi-lethal effect of the gene responsible in regions of warmer climate. Consequently a north to south gradient is produced in white gene frequency, there being nearly 100 per cent white in the far north.

Correlated with this white gene are other minor genes modifying its effects and the effects of the orange color factors. But little is known of these beyond the fact that they are in different concentrations in widely separated locations, that they can be selected for in genetic experiments and that some of them seem to control the lethality or semi-lethality of the white females. The chemical structure of the chitin in the adult is directly affected by the more extreme combinations; the lethal effects seem to be regulated by still more extreme combinations in connection with the dominant factor mentioned above. A rarer isolated gene has recessive effects but these are very extreme, both in the male and in the female As in the effects by the dominant gene and the minor recessive modifiers, this one gives a whiter color to the adults and a weaker chitin structure to the body.

As the genes controlling the above characters are intimately related to genes controlling development rate and quality of development (Hovanitz 1944b), the significance of these differences to the possible chemical control of insects is apparent. An insect with a more rapid metabolic rate and a weaker chitin structure, might be expected to succumb to chemical poisons more quickly than others. The genetic nature of insecticide resistance in insects is a known fact (Quayle 1938; Dickson 1941).

HYBRIDIZATION.—The two races of *Colias chrysotheme* in North America (the alfalfa butterfly and the clover butterfly) interbreed and produce fertile hybrids in localities where they coexist. This occurs most frequently in those places where the respective food plants, clovers and alfalfa, exist together in the same fields (Hovanitz 1943b).

The physiological effect of the hybridization, though it does not appear to produce sterilization directly, does account for a very high mortality of the hybrid individuals (Hovanitz 1944b) as a direct product of the crossing. Likewise, there will be a high frequency of sterility in the adults owing to the larvae feeding on the wrong food plant. Yellow-race individuals are always sterile when grown on alfalfa. The evidence is great that the orange race individuals are sterile when grown on red clover. Females of either parent have a laying preference but err frequently in choice. Consequently the hybrids might be of either food type or of an intermediate type. But in any case, a high degree of sterility will result from growth upon the wrong plant. In combination with high mortality from the effects of poor gene combinations, this sterility will aid in the reduction of Colias population numbers, perhaps below the economic level.

At the present time, these coliads are not agricultural pests in any area where these conditions are present. The hybridization may be the controlling factor in such areas (east of a line drawn along the Sierra Nevada-Cascade divide, then to southern Utah and south along the continental divide—see map, Hovanitz 1944a). At any rate, it seems highly reasonable to assume that a natural control of these pests would be possible by such a means as growing red clover and alfalfa mixed, thereby reducing the *Colias* pests of each by having one race act against the other.

SUMMARY AND CONCLUSIONS.—Physiological and genetical data on the alfalfa and clover butterflies of North America have indicated that there are several

means by which a natural control of these insects is now in progress and several means by which it would be possible for ranchers in some geographical areas to disrupt the normal living conditions in order to reduce the populations below economic levels of abundance. These are:

1. The behavior of a *Colias* female in laying her eggs is primarily that of a transient, a single egg being laid at one time and in one place. Therefore it is necessary that there be great numbers of females available in the vicinity of a freshly cut field if the eggs are to be laid in a field in sufficient numbers at the right time to have a disastrous effect upon the crop. To be effective the eggs must be laid upon the plants in the few days immediately following a previous cutting. The females laying these must come from nearby uncut fields or portions of fields where they are emerging. Great destruction would be produced by the ranchers in a neighborhood upon *Colias* by cutting fields in cooperation so that the fields of one rancher will not produce the adults which lay eggs upon those of his neighbor. With intelligent observation and control of cutting time, any generation of *Colias* can be nearly completely destroyed in any region.

2. The destructiveness of *Colias* is closely correlated with climatic conditions and abundance of alfalfa fields. The physiological limits of *Colias*, where known, can often be correlated with these factors in such a way that by a slight man-made manipulation, the balance of lethal conditions can be turned against the insect. This is the case in the hot, arid regions of California and Arizona where the heat-protection places for adults can be eliminated easily. In the same regions, by the elimination of the adult source of food, the egg laying capacity of the females can be cut to 5 per cent or less.

3. A suggestion is made that by providing conditions for hybridization and larval food mixups between the alfalfa and the clover races in North America, the resultant sterilization and high mortality may reduce the populations to very low levels. Neither race is now a pest in any region where these conditions exist.

4. Other genetic and physiological variations and fluctuations are discussed for which no practical use is yet apparent. One of the potentially important of these is the geographical differences in physiological properties of strains from geographically segregated populations which are visibly alike. When tests of chemical poisoning are made, one will need to bear in mind the fact that the metabolic rate and chitin strength will be variable in different strains.

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Dr. Horace Greeley Johnston has been named Director of Research for the Freeport Sulphur Company, succeeding Dr. P. D. Peterson who becomes Agricultural Research Director for the American Fruit Growers, Inc., Hagerstown, Maryland.

Dr. Johnston will have particular interest in the sulphur products produced for use as insecticides and fungicides and will, no doubt, maintain the cooperation which has existed between the Freeport Company and the entomologists concerned with these products in the past. Dr. Johnston has been active in the field of Entomology for many years, most of his professional experience having been gained in Arizona and Texas.

Latent Injury from Pyrethrum and Rotenone Dusts

HARVEY L. SWEETMAN and GEORGE G. GYRISKO, *Massachusetts State College, Amherst*

It was observed in a series of insecticidal tests with pyrethrum and rotenone dusts that firebrats, *Thermobia domestica* Pack., which survived the acute toxic effects of the poison frequently suffered from a latent injury. Roy & Ghosh (1942) reported on a third active principle of pyrethrum, which was not complimentary to pyrethrin I and II. Their original paper has not been seen, and it is not known if they were dealing with the same phenomenon that is discussed in this paper.

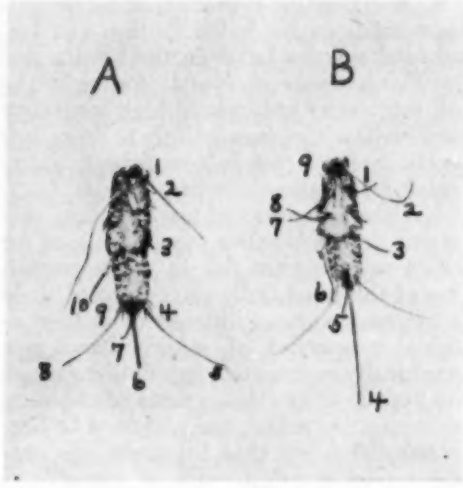

FIG. 1.—The latent injury from pyrethrum dust as exhibited by the blackened portions of exuviae of firebrats, *Thermobia domestica* Pack.

Key to blackened portions of appendages.

A

1. Stubs of labial palpi.
2. Distal segments of maxillary palpi.
3. Femoral stub of metathoracic leg; tarsus of mesothoracic leg.
4. Three sternal abdominal appendages.
5. Distal fourth of cercus.
6. Stub tip of telson.
7. Ovipositor.
8. Distal fifth of cercus.
9. Tip of abdomen; stub of first sternal abdominal appendage; second and third sternal abdominal appendages.
10. Tibia and tarsus.

B

1. Distal third of maxillary palpus.
2. Distal third of antenna.
3. Distal tip of tarsus.
4. Distal tip of telson.
5. Ovipositor.
6. Distal third of tarsus.
7. Distal half of antenna.
8. Tarsus.
9. Stubs of three palpi and other portions of mouthparts.

The insects on exposure to the dusts usually were paralyzed in a few seconds or at most few minutes depending on the amount of dust coming into contact with their bodies. This acute toxicity, if sufficient to kill, usually did so within three, or at most five days. If death did not occur during the first few days partial or complete recovery from the acute paralysis usually followed. Evidence of recovery was usually noticeable on the second day, frequently before the symptoms of latent injury of the appendages occurred. The insects that survived severe paralysis always developed the latent symptoms, although slightly paralyzed individuals might not show the latent effects. On the other hand, insects that exhibited little or no paralysis often developed the latent symptoms.

This latent injury was exhibited by complete or partial blackening and loss of use of portions of various appendages as legs, antennae, telson, cerci, labial and maxillary palpi, ovipositor, and sternal abdominal appendages (Fig. 1). Apparently death of the tissue preceded the discoloration. The dying of the tissue and discoloration were progressive and frequently continued for several weeks. The blackened distal portions of appendages gradually sloughed off as death of the tissue progressed. In some tests very little discoloring of the appendages occurred, but typical sloughing off of the injured portions was evident during the first few days following treatment (Tables 5 and 6). Recovery from such mild cases of injury was usually complete following the molt succeeding treatment. The typical latent injury showing discoloration frequently resulted in death of the firebrats, but death may have been secondary in many instances. The injury often progressed so far that only stubs of legs or other appendages remained and normal activities were often restricted or prevented.

Insects suffering from progressive latent injury could not necessarily eliminate

the toxic action by molting, although a few individuals recovered (Table 3). The blackened portions of appendages on the exuviae were conspicuous (Fig. 1), but the same appendages on the new body wall usually showed similar or more advanced discoloration.

All of the tests reported in this paper were conducted at or near 27° C., a temperature near room conditions, but considerably below the optimum for reproduction (37°) for the firebrat. The relative humidity was maintained near 80 per cent. The latent symptoms were reduced and the percentage of recovery was greater at 37°. Only a limited number of the tests were conducted in the optimum environment since the toxicity of pyrethrum dust declined rapidly under those conditions.

A series of tests were made to gain further information regarding this latent injury. Both rotenone and pyrethrum dusts were used in an early series (Table 1). These dusts were placed in receptacles about one inch square and three-sixteenths of an inch deep made from paper towels. These receptacles with the insecticides were placed in glass dishes about eight inches in diameter which contained the insects. The insects were free to avoid or to crawl over the insecticidal dusts. They showed little ability to detect or avoid the dusts during the first day or two, although they did not crawl over the insecticides so much there after. This may not have been an avoidance reaction but the result of partial inability to crawl over the edges of the paper receptacles because of the injury to appendages contracted during the first few days of the tests. About 50 per cent of the insects in this series were killed by acute toxicity, the remainder dying from the latent effects over a period of several weeks. The results were quite similar with the two insecticides, although from casual observations it seemed that the latent injury appeared sooner and more extensively from rotenone than from pyrethrum. The combination of pyrethrum and rotenone produced more discoloration than either dust alone.

Table 1.—The effects of pyrethrum and rotenone dusts on firebrats, *Thermobia domestica* Pack., when exposed to a continuous source of the insecticides.

Method of Application	Number of Insects	Deaths from Acute Toxicity	Latent Injury: Number of Insects	Latent Injury: Days to Kill
	Rotenone			
Heavy dust in paper receptacle	7	4	1	2
			1	2
			1	46
	Pyrethrum			
Heavy dust in paper receptacle	17	9	2	2– 4
			3	6– 8
			3	10–20
Light dust in paper receptacle	6	2	2	5– 8
			2	19–24

An attempt was made to determine what effect length of exposure to pyrethrum dust had in producing the manifestations of latent injury. A layer of dust was deposited on glass dishes and the insects exposed for various periods of time. The exposure of individuals varied considerably since the irritation from the insecticide often produced frantic struggling of the insects and some would roll in the dust

Table 2.—The effects of pyrethrum dust on firebrats, *Thermobia domestica* Pack., when exposed to the insecticide for one to seven minutes.

Number of Insects	Exposure in Minutes	Injury First Noticeable. Days	Percentage Dead in Two Days	Percentage Dead in Seven Days	Percentage Dead in 14 Days	All Dead. Days
5	1	5	0	0	0	47
5	2	5	0	20	20	57
5	2.5	2	20	20	40	43
5	3	2	40	60	60	49
5	3.5	2	40	40	60	41
5	4	1	0	20	40	52
5	5	2	0	60	80	45
15	7	2	13	73	93	26
			Check			
5	—	—	0	0	0	—

Table 3.—The effects of pyrethrum dust on firebrats, *Thermobia domestica* Pack., when exposed to the insecticide for two to sixty seconds.

Seconds Exposed	Number of Insects	Per Cent Dead							
		Days	Weeks						
		5	1	2	4	8	12	16	19
2	16	25	25	25	25	38	38	75	75
5	20	0	0	0	0	0	15	20	20
10	20	30	30	35	50	65	85	100	—
15	20	35	35	50	50	70	80	90	100
20	20	0	0	15	15	30	45	65	75
25	22	9	9	23	23	40	55	70	73
30	20	30	40	55	55	55	60	85	85
40	20	25	30	30	40	45	55	55	95
60	20	55	70	75	75	80	100	—	—
Check	20	—	—	—	—	—	—	—	15

while others remained on their feet. The activities of the insects always increased greatly in 2 to 3 seconds after exposure to the insecticides. The treated insects were removed to a clean dish after specified periods of time.

The results of exposing the insects to a very thin layer of dust for periods of one to seven minutes is shown in table 2. Deaths from acute toxicity were not great in most exposures of this series while the deaths from latent injury were high. Probably most if not all of the deaths were produced by the insecticidal action as none of the check insects died during the experimental period demonstrating the suitability of the general environment. The effects of the period of exposure to the insecticide are very noticeable at the end of two weeks. Some of the insects suffering from latent injury lived for as much as two months.

The results of exposing the insects to pyrethrum by a similar technique to a heavier layer of dust for shorter periods of time are given in table 3. In some of the tests of this series the number of deaths was not recorded until the fourth or fifth day, but the majority of those dead at that time had probably died on the first and second days. The latent injury persisted for as much as 19 weeks and still was apparently producing death. None of the check lot of insects had died until the nineteenth week. It appears that three-fourths or more of the deaths were produced by the latent effects of the insecticide. When the experiment was closed at the end of 19.5 weeks, 20 per cent of the insects were alive, but nearly half of these were from the 5-second exposure. Forty-three per cent of the survivors were still suffering from latent injury. These insects had molted three or more times during this interval (Fig. 1); (Sweetman 1934; Sweetman & Whittemore 1937).

Table 4.—Evidence of latent injury to firebrats *Thermobia domestica* Pack., from dusting of pyrethrum in their natural habitat.

Date Collected May	Pyrethrum Treatment	Number of Insects Collected	Number with Latent Injury
8–12	None	125	None
14	Floor dusted	4	1
16–17	None	44	None
18–20	Floor dusted	34	1?

An attempt was made to ascertain if typical symptoms of latent injury occurred when pyrethrum dust was applied for control of firebrats in their natural environment (Table 4). Trapping for 4 days before treatment yielded 125 individuals, none of which showed any injury typical of the latent type. Following the application of the dust on May 13, four paralyzed insects were collected among many dead ones. Three of these died within 24 hours but one lived for 13 days and showed typical symptoms of latent injury on its cerci, tarsi, palpi, and antennae. A second collection by trapping before dusting yielded 44 insects, none of which showed any injury that could be interpreted as latent pyrethrum injury. No paralyzed insects were observed on the floor among the dead

Table 5.—A detailed record of observable injury from a mild case of latent injury on firebrats, *Thermobia domestica* Pack., R-right; L-left; A-antennae; T-telson.

INSECT NUMBER	CONDITION OF APPENDAGES WHEN TESTED	CONDITION AFTER TREATMENT	CONDITION AFTER MOLTING
1	Normal	RC, T-end off; LC-end off, tip black	Normal
2	Normal	LC-¼ off; T-end off, tip black	Normal
3	LC-¾ off; T-¾ off	Slight paralysis; RC-½ off; A-ends off; T* end off, tip black; died in molting, head caught	Dead
4	Normal	LC-½ off; RC, T-tips black; RA-end off	Normal
5	Normal	LC-¼ off; T-end off, tip black	Normal
6	Normal	RC-⅔ off, tip black; LC-end off; T-tip black	Normal
7	Normal	LC-½ off, tip black; RC-¾ off, tip black; T-¼ off, tip black	Normal

specimens after dusting. Trapping for 2 days following this dusting on May 17 yielded 34 insects. Since these insects were able to enter the trap, they presumably had suffered little or no paralysis from the insecticidal treatment. Three weeks later one individual showed traces of tarsal injury that might have been of the latent type.

The above symptoms of latent injury were very evident in tests with firebrats over a period of several years, but were much reduced in 1944. Several samples of pyrethrum dust that had produced fatal latent injury on preceding years as well as one new package of dust produced much less severe injury with few fatalities. The results of one of these tests are listed in table 5. The insects were handled individually and a detailed record of the condition of all appendages of each insect was recorded before and during the tests. Portions of the antennae, cerci, and telson sloughed off and discoloration was slight. This injury was not progressive and the insects were normal after molting as would have occurred if the damage to the appendages had been produced by mechanical means. One insect, No. 3, died in molting as had often occurred in previous tests when they were afflicted with latent injury. This individual had a cercus and a telson broken when tested, but only the head was not successfully withdrawn from the exuvia. This suggests that discoloration of the injured appendages from pyrethrum can be accepted as a good criterion of progressive latent injury. The acute toxicity from the dusts was near normal in several similar tests when sufficient dust or longer exposures were used (Table 6). However, few deaths resulted from the latent injury, which was not progressive as in previous years. Practically complete recovery was attained with the first succeeding molt following the treatment. Six control firebrats used in this series remained entirely free of broken appendages during the test.

Table 6.—A summary of the effects of several samples of pyrethrum dust on firebrats, *Thermobia domestica* Pack., that produced light latent injury.

DUST	INSECTS	DEATHS	LATENT INJURY			
			Noticeable	Not Detectable	Recovered	Died
Heavy	28	11	13	4	10	3
Light	32	4	15	13	15	0
Check	6	0	0	0	—	0

SUMMARY.—It was observed in a series of tests that pyrethrum and rotenone dusts produced a latent injury among firebrats. The symptoms of the injury were exhibited by discoloration and sloughing off of various afflicted appendages. When discoloration of the appendages occurred the injury was progressive and death followed in from a few days to weeks. Some samples of pyrethrum did not produce the typical latent symptoms.—8-24-44.

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Humidity in Relation to the Ovicidal Effect of Powders Used Against the Body Louse[1]

ELTON J. HANSENS

In laboratory and field studies of the effectiveness of chemicals used against eggs of the body louse, *Pediculus humanus corporis* Deg., it was noted that the number of eggs killed by larvicidal powders varied at different times. In the laboratory it was found that the efficacy of the powders varied with changes in the humidity in the incubator where the eggs were kept during the testing routine. Failure of powders in the field could not be attributed entirely to faulty application or to any other obvious condition, and it was thought that here too humidity might have an important influence on the ovicidal activity of powders. In order to secure information on this subject a series of experiments was planned to determine the effect of humidity on several of the materials which had been found most destructive of body louse eggs in routine laboratory tests.

The literature dealing with the effect of humidity on the eggs of lice is limited. Buxton (1939) states that it is not known whether the egg is sensitive to low humidity. He further states that in nature humidity may be a controlling factor in certain parts of the world, and that the effect of humidity on lice is a subject which urgently demands study.

Mellanby (1932) made measurements of temperature and humidity between the clothes and the body of a resting person. He found that when the air beneath the shirt ranged between 23° C. and 37° C. the relative humidity was between 23 per cent and 70 per cent. March and Buxton (3) made similar observations in cold and hot seasons in south Persia and their data were consistent with those of Mellanby.

Bredenkamp (1942) in studying the effect of temperature and moisture on the penetrating power of pyrethrum, barbasco root (5 per cent rotenone), and dinitro-ortho-cresol, observed that at low temperatures and corresponding humidities a longer time elapsed before symptoms of poisoning appeared in larvae of *Lymantria monacha* than when high temperatures and humidities were used. Humidity seemed to be more important in this connection than temperature. No references to the effect of humidity on ovicides could be found in the literature.

MATERIALS AND METHODS.—The materials used in the studies reported here were those which had given the best results in routine laboratory tests. Some of the materials had been tested in the laboratory of the United States Department of Agriculture, Bureau of Entomology and Plant Quarantine, Orlando, Florida, and were made available through the cooperation of Mr. E. F. Knipling.

The usual laboratory procedure for obtaining eggs was as follows: One hundred female and 125 male lice were placed on a piece of 33 per cent woolen underwear cloth glued to a metal disk. These disks, with the lice, were placed in 100 cc. beakers, the disks being just large enough to fit in the bottom of the beakers. The lice were kept in an incubator operating at 29° C. and about 50 per cent relative humidity. Each day the lice were moved to fresh cloths, and dead individuals were replaced by males or females from the laboratory colony in order to maintain a standard ratio of males and females in the colonies used for obtaining eggs. The lice were fed twice each day, at about 8 A.M. and 5 P.M., on human volunteers. The number of disks maintained depended on the number of eggs desired for testing purposes. The cloth disks were kept in the incubator until the eggs reached the age desired for the particular test in hand.

The routine tests were made on 2-day-old and on 6-day-old eggs. When the eggs were to be tested the disks of cloth were cut into pieces each of which contained 20 eggs, a number found to be convenient for counting and handling. These lots of eggs were treated with powders by dusting the surface of the cloth heavily and shaking off the excess powder. The cloths were then placed in labeled vials and set aside in an incubator at a temperature of 28° C. and relative humidity of 60 to 70 per cent. After 21 days the eggs were examined and

[1] From the Laboratories of the International Health Division of The Rockefeller Foundation, New York.

recorded as being hatched or unhatched.

In the present studies eggs were handled in the manner outlined above except that they were maintained at a temperature of 30° C. and varying humidities for the 21-day exposure period.

Two methods were employed in securing the desired relative humidities. Saturated solutions of various salts were used in the early tests and various dilutions of sulfuric acid in the later ones. About 200 ml. of the solutions were placed in the bottom of battery jars. A quarter-inch mesh, galvanized wire screen was suspended above the solution surface, and the vials containing the dusted cloths bearing eggs were placed on the screen in an upright position. No corks or other coverings were used on the vials. The jar was covered with the top of a large petri dish and the top edge of the jar was coated with "celloseal" or vaseline to make a tight joint between the jar and the cover. Test jars were kept in the incubator at 30° C. except when vials were being put into or removed from the jars.

Two series of tests were made using salt solutions for obtaining the desired humidity. The salts used and the humidities obtained were as follows:

	Salt	*Humidity* Per Cent
Series I Jar No.		
1	$CaCl_2$	11
2	$LiCl \cdot H_2O$	20
3	$K_2CO_3 \cdot 2H_2O$	30
4	NaCl	61
5	$NaBr \cdot 2H_2O$	62
6	$Mg(C_2H_3O_2)_2 \cdot 4H_2O$	68
Series II Jar No.		
9	NH_4Cl	64
11	$ZnSO_4$	68
13	Na_2SO_4	68
16	$Zn(NO_3)_2$	68
10	$(NH_4)_2SO_4$	73
8	NaH_2PO_4	74
7	KNO_3	84

The humidities listed above were those recorded by a hair hygrometer placed in the respective jars until the reading became constant. Jars 12, 14, and 15 contained salts which gave very high humidities, and tests carried out in these jars were discarded because of the growth of mold on the test cloths.

The third series consisted of the following concentrations of sulfuric acid and the corresponding relative humidities:

Per cent H_2SO_4 Conc.	*Humidity* Per Cent
62	15
56	25
52	33
48	42
44	49
39	58
36	66
33	70
27	80

In the first run of Series I a single material was tested by placing two treated lots and one untreated control lot in each of the jars. On consecutive days the other materials were tested. In the second run of Series I two samples dusted with each of the powders, together with two control lots, were placed in one of the jars and the tests were repeated on consecutive days until all lots had been exposed in every jar of the series. Since no difference was noted between the methods of treatment, samples of different materials were placed in a jar at one time and left for the exposure period. This method reduced the number of untreated lots which had to be handled as controls on the treatments. Tests were made on both 2-day-old and 6-day-old eggs.

MATERIALS TESTED.—All of the materials tested were powders prepared by dissolving the toxic materials in acetone and mixing them with the required amount of pyrophyllite (*Pyrax ABB*) in a mortar until the acetone evaporated. In the fine, uniform powder which resulted from this treatment theoretically every particle contained a portion of the toxic materials. Materials tested in all jars included the following: Phenothioxin 1 and 10 per cent; phenothioxin 1 per cent and 3, 5-dinitro-o-cresyl acetate 1 per cent; 3, 5-dinitro-o-cresyl acetate 1 and 10 per cent; 2, 4-dinitro anisole 1 and 10 per cent; *MYL*, a powder developed by the Orlando, Florida, laboratory of the Bureau of Entomology and Plant Quarantine, containing 2, 4-dinitro anisole 2 per cent, pyrethrins 0.2 per cent, phenol S 0.25 per cent, N-isobutyl undecylenamide 2.0 per cent; and 2, 4-dinitro phenetole 1 and 10 per cent. In addition to the above the third series included tests with 1 and 10 per cent concentrations of the following materials:[1] Methyl p-amino benzoate,

[1] These materials were furnished through the cooperation of Mr. E. F. Knipling, Senior Entomologist, Bureau of Entomology and Plant Quarantine, Orlando, Florida.

Table 1.—Per cent of 2-day old eggs of the body louse killed by louse powders at the humidities indicated.

Per Cent Humidity	11	20	30	61	62	64	68	68	68	68	73	74	84	
Jar Number	1	2	3	4	5	9	6	11	13	16	10	8	7	Standard Test 60 to 70% Humidity
Number of Tests	6	6	6	6	6	2	6	2	2	2	2	2	2	
Material														
Phenothioxin 1%	11.0	12.5	9.0	61.0	16.5	17.5	18.5	45.0	62.5	75.0	37.5	22.5	67.5	67.5
10%	16.5	15.0	18.5	29.0	19.0	35.0	91.0	97.5	100.0	100.0	100.0	100.0	100.0	61.5
Phenothioxin 1% and Dinitro cresyl acetate 1%	15.0	9.0	6.5	47.5	56.0	47.5	100.0	100.0	97.5	100.0	100.0	95.0	90.0	90.0
Dinitro cresyl acetate 1%	19.0	11.5	28.5	30.0	52.5	37.5	92.5	95.0	85.0	90.0	62.5	95.0	75.0	99.0
Dinitro cresyl acetate 10%	23.5	16.5	16.0	94.0	96.0	85.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Dinitro anisole 1%	13.0	8.5	18.5	66.5	85.0	87.5	98.5	100.0	100.0	100.0	100.0	90.0	100.0	96.5
Dinitro anisole 10%	10.0	11.0	16.5	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
MYL	14.0	13.0	13.5	97.5	99.0	100.0	110.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Dinitro phenetole 1%	16.5	11.0	20.0	65.0	81.0	55.0	100.0	100.0	100.0	100.0	100.0	87.5	97.5	95.0
Dinitro phenetole 10%	7.5	11.0	9.0	82.5	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Untreated eggs	9.0	7.5	8.5	8.5	8.0	20.0	12.5	37.5	22.5	27.5	17.5	15.0	20.0	13.0

azoxybenzene, 2, 4-dinitro phenol, and tertiary butyl valone. Also included were 1 and 5 per cent concentrations of diethyleneglycol diester of chloracetic acid. Only a 5 per cent concentration of this material could be made into a dustable powder because it is a liquid.

Results.—The percentage of dusted eggs killed after exposure to the indicated humidities of Series I and II is tabulated for 2-day-old eggs in table 1 and for 6-day-old eggs in table 2. Series I and II have been combined in these tables since the same method of obtaining humidity, namely saturated salt solutions, was used in the two series. Thus a complete range of humidities is shown in a single table. However, it should be noted that fewer tests were made in Series II and the results are therefore less conclusive than those obtained in Series I. In the tables the jar number has been recorded to indicate the salt used for obtaining the desired humidity as given above. The number of tests at each humidity are also indicated. The column entitled "standard test" gives data for tests conducted simultaneously with the other tests but placed in the incubator used for routine tests.

Results of tests in which sulfuric acid

Table 2.—Per cent of 6-day old eggs of the body louse killed by louse powers at the humidities indicated.

Per Cent Humidity	11	20	30	61	62	64	68	68	68	68	73	74	84	
Jar Number	1	2	3	4	5	9	6	11	13	16	10	8	7	Standard Test 60 to 70% Humidity
Number of Tests	4	4	4	4	4	2	4	2	2	2	2	2	2	
Material														
Phenothioxin 1%	7.5	6.5	5.0	11.5	10.0	12.5	9.0	25.0	15.0	55.0	42.5	32.5	30.0	8.0
10%	15.0	6.5	14.0	11.5	35.0	22.5	86.5	85.0	100.0	100.0	100.0	100.0	100.0	65.0
Phenothioxin 1% and Dinitro cresyl acetate 1%	7.5	11.5	7.5	61.5	55.0	20.0	80.0	100.0	100.0	100.0	87.5	100.0	87.5	80.0
Dinitro cresyl acetate 1%	17.5	11.5	13.0	25.0	52.5	19.5	90.0	82.5	82.5	85.0	80.0	62.5	65.0	70.0
Dinitro cresyl acetate 10%	14.0	12.5	15.0	96.5	94.0	75.0	100.0	100.0	100.0	100.0	100.0	100.0	92.5	98.5
Dinitro anisole 1%	9.0	7.5	12.5	62.5	70.0	52.5	92.5	100.0	100.0	100.0	100.0	100.0	100.0	64.5
Dinitro anisole 10%	7.5	12.5	11.5	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	92.5
MYL	21.5	9.0	4.0	100.0	99.0	100.0	96.5	100.0	100.0	100.0	100.0	100.0	100.0	92.5
Dinitro phenetole 1%	7.5	9.0	24.0	34.0	69.0	100.0	97.5	90.0	100.0	100.0	100.0	100.0	100.0	83.0
Dinitro phenetole 10%	11.5	11.5	7.5	64.0	95.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	98.0
Untreated eggs	8.0	5.5	10.0	11.5	10.0	12.5	6.0	15.0	21.5	10.0	27.5	15.0	24.0	9.5

solutions were used to obtain the desired humidity are given in table 3 for 2-day-old eggs and in table 4 for 6-day eggs. Data for all 20 powders tested are summarized in these tables. With each material four tests were made at each humidity, except in the case of 6-day eggs at zero and 80 per cent humidity where two tests were made with each material. "Standard test" again refers to the simultaneous tests using routine laboratory test procedure.

Table 3.—Per cent of 2-day old eggs of the body louse killed by louse powders at the humidities indicated.

Material		Per Cent Relative Humidity										Standard Test
		0	15	25	33	42	49	58	66	70	80	
Phenothioxine	1%	22.5	52.5	24.0	19.0	22.5	17.5	10.5	9.0	20.0	20.0	67.5
	10%	44.0	47.5	11.5	14.0	11.5	22.5	30.0	42.5	36.5	57.5	61.5
Phenothioxine 1% cresyl acetate	1%	50.0	37.5	30.0	17.5	20.0	24.0	17.5	37.5	31.5	86.5	95.0
Dinitro cresyl acetate	1%	26.5	50.0	26.5	14.0	19.0	17.5	15.0	11.5	19.0	81.5	99.0
	10%	60.0	60.0	51.5	34.0	29.0	41.5	49.0	54.0	65.0	100.0	100.0
Dinitro anisole	1%	25.0	35.0	12.5	20.0	15.0	7.5	27.5	22.5	39.0	91.5	96.5
	10%	27.5	25.0	22.5	17.5	16.5	24.0	36.5	65.0	97.5	100.0	100.0
MYL		29.0	35.0	26.5	22.5	19.0	20.5	29.0	51.5	70.0	100.0	100.0
Dinitro phenetole	1%	26.5	37.5	12.5	16.5	14.0	16.5	16.5	21.5	29.0	100.0	95.0
	10%	25.0	40.0	25.0	14.0	19.0	24.0	41.5	29.0	80.0	100.0	100.0
Methyl p-amino benzoate	1%	26.5	19.0	16.5	17.5	6.5	14.0	11.5	72.5	100.0	100.0	54.0
	10%	16.5	16.5	12.5	7.5	5.0	11.5	6.5	100.0	100.0	100.0	99.0
Azoxybenzene	1%	29.0	16.5	11.5	11.5	11.5	9.0	17.5	35.0	20.0	48.0	64.0
	10%	39.0	29.0	25.0	36.5	35.0	30.0	81.5	30.0	85.0	90.0	75.0
Diethyleneglycol diester of chloracetic acid	1%	27.5	30.0	7.5	10.0	9.0	14.0	6.5	6.5	10.0	21.5	11.5
	5%	24.0	24.0	9.0	11.5	7.5	14.0	9.0	14.0	27.5	11.5	37.5
2,4 Dinitro phenol	1%	25.0	15.0	10.0	19.0	11.5	19.0	11.5	14.0	16.5	57.5	49.0
	10%	30.0	46.5	56.5	36.5	11.5	32.5	21.5	94.0	97.5	96.5	96.5
Tertiary butyl valone	1%	37.5	46.5	15.0	12.5	12.5	27.5	5.0	79.0	77.5	100.0	96.5
	10%	100.0	100.0	95.0	82.5	97.5	100.0	95.0	100.0	100.0	100.0	100.0
Untreated		26.5	21.0	11.5	7.5	10.0	9.0	16.0	13.0	13.5	7.5	12.5

Discussion.—In table 1 it will be noted that good ovicidal results were obtained with all materials on 2-day-old eggs by the usual laboratory test. Similar mortality was obtained in most cases when the humidity was 68 per cent or above. Results obtained when the humidity was between 61 per cent and 68 per cent are somewhat erratic, but with humidities below 60 per cent relative humidity no appreciably greater mortality occurred than in the lots of untreated eggs. There was considerable variation in the mortality of eggs, particularly with the tests of Series II (Jars 9, 11, 13, 16, 10, 8, and 7), where fewer tests were made. Probably these results would have been comparable with the others if a greater number of tests had been conducted.

The results summarized in table 2, giving the percentage of unhatched 6-day eggs treated with the indicated powders, are similar to those obtained with 2-day eggs. It will be noted that in nearly every case less 6-day eggs were killed. This probably can be explained on the basis of the shorter exposure of the 6-day eggs to the powders before hatching occurred. No appreciable kill was obtained at low humidity. With humidity between 60 and 68 per cent the results were variable but kills tended to be good. Satisfactory kills were obtained at humidities of 68 per cent and higher.

In both of these tables it is evident that 10 per cent powders gave effective kills over a wider range of humidity than 1 per cent powders. Also, these tests showed that phenothioxin and 3, 5-dinitro-o-cresyl acetate are not as effective over a wide range of humidity as are 2, 4-dinitro anisole, 2, 4-dinitro phenetole and powder MYL.

Further data on the humidities between 30 and 60 per cent are summarized in tables 3 and 4 for 2-day and 6-day eggs respectively. In these results additional data are included on the materials shown in tables 1 and 2. However, all the

data presented in tables 3 and 4 are on tests from jars where sulfuric acid dilutions were used to obtain the indicated humidities. Results are given for five materials not included in earlier tests.

These two tables show several interesting effects of humidity on the activity of ovicides used against louse eggs. Again 2-day eggs, in general, were killed more readily than 6-day eggs, although the differences were slight. It is evident that the effectiveness of ovicides was increased in every case by a higher humidity. At very low humidities (zero and 15 per cent) the killing effect was slightly higher than at a humidity of 25 per cent, but it will be noted that a greater mortality of untreated eggs was obtained at the low humidities. This greater mortality of untreated eggs compensates for the higher kill at low humidity, and the above hypothesis is not invalidated.

As might be expected a 10-per cent concentration of the toxic ingredient was more effective and killed eggs over a wider range of humidity than a 1-per cent concentration of the same material. Also the relative effectiveness of powders was indicated by these tests. A comparison of results at 80 per cent humidity showed that 1- and 10-per cent concentrations of dinitro-o-cresyl acetate, dinitro anisole, *MYL*, dinitro phenetole, methyl p-amino benzoate, and tertiary butyl valone, and a 10 per cent concentration of 2,4-dinitro phenol had essentially the same toxicity. At 70 per cent humidity, however, the 1-per cent concentrations were no longer toxic and 10-per cent concentrations of dinitro cresyl acetate, *MYL*, and dinitro phenetole had lost much of their effectiveness. Similarly, tertiary butyl valone was seen to be by far the most effective ovicide. It gave good kills at all humidities in a 10-per cent concentration and was the only ovicide which gave high mortality at humidities below 66 per cent.

Certain discrepancies appear in the data, but it was thought that many of these would disappear with additional tests. The results presented in tables 3 and 4 show that lower mortality was obtained than in the test results summarized in tables 1 and 2. In the tests of the sulfuric acid series (Tables 3 and 4) more vials were exposed at one time in each of the jars with the result that the jars were opened more frequently and therefore the actual humidities were lower than indicated. No hygrometer of sufficient accur-

Table 4.—Per cent of 6-day old eggs of the body louse killed by louse powders at the humidities indicated.

Material		Per Cent Relative Humidity										Standard Test
		0	15	25	33	42	49	58	68	70	80	
Phenothioxine	1%	15.0	24.0	31.5	12.5	11.5	22.5	11.5	12.5	20.0	17.5	8.0
	10%	15.0	25.0	26.5	22.5	11.5	24.0	24.0	27.5	14.0	70.0	65.0
Phenothioxine 1% cresyl acetate	1%	25.0	56.5	19.0	35.0	21.5	12.5	31.5	17.5	34.0	92.5	80.0
Dinitro cresyl acetate	1%	15.0	25.0	16.5	30.0	16.5	20.0	15.0	15.0	20.0	57.5	70.0
	10%	20.0	41.5	47.5	36.5	21.5	26.5	45.0	39.5	72.5	100.0	98.5
Dinitro anisole	1%	22.5	15.0	20.0	10.0	16.5	20.0	11.5	21.5	37.5	90.0	64.5
	10%	7.5	29.0	20.0	12.5	10.0	21.5	16.5	34.0	84.0	100.0	92.5
MYL		10.0	34.0	21.5	11.5	12.5	17.5	12.5	29.0	57.5	100.0	92.5
Dinitro phenetole	1%	17.5	19.0	14.0	20.0	11.5	10.0	11.5	15.0	20.0	85.0	83.0
	10%	20.0	15.0	16.5	24.0	30.0	20.0	20.0	37.5	54.0	100.0	98.0
Methyl p-amino benzoate	1%	2.5	7.5	16.5	6.5	15.0	9.0	9.0	9.0	97.5	100.0	70.0
	10%	5.0	15.0	14.0	9.0	11.5	7.5	12.5	30.0	95.0	100.0	98.5
Azoxybenzene	1%	10.0	9.0	17.5	16.5	12.5	10.0	17.5	9.0	7.5	50.0	8.5
	10%	10.0	12.5	14.0	16.5	11.5	5.0	11.5	6.5	12.5	77.5	78.5
Diethylene glycol diester of chloracetic acid	1%	10.0	9.0	9.0	9.0	14.0	6.5	10.0	7.5	17.5	37.5	10.0
	5%	12.5	12.5	14.0	11.5	9.0	10.0	5.0	20.0	17.5	20.0	25.0
2,4 Dinitro phenol	1%	10.0	19.0	11.5	12.5	9.0	11.5	9.0	32.5	2.5	20.0	98.5
	10%	30.0	22.5	26.5	16.5	31.5	25.0	49.0	97.5	90.0	100.0	70.0
Tertiary butyl valone	1%	17.5	36.5	34.0	28.5	29.0	32.5	14.0	75.0	62.5	100.0	100.0
	10%	100.0	100.0	100.0	100.0	95.0	59.0	99.0	100.0	100.0	100.0	100.0
Untreated		15.0	13.0	12.5	11.0	12.0	11.5	6.5	10.5	7.5	10.0	9.5

acy was available for checking the actual humidity in the jars. Nevertheless, the various tests in the series are thought to be comparable, and the same trends are noted in all four tables. More reliable results could have been obtained by sealing a test vial in a jar and leaving it until hatching was complete. By so doing the desired humidity would have been maintained throughout the exposure period.

The data presented above are important both from the standpoint of laboratory testing and field control. According to Mellanby (1932) the humidity beneath the shirt of a man ranges between 27 and 70 per cent. Thus, if an ovicide was to be effective it would have to act between these extremes of humidity. The tests described above showed that only one of the materials was effective throughout this range of humidity although the usual laboratory tests had shown that all of the materials tested except phenothioxine were effective ovicides.

For a screening test in the laboratory a high humidity would determine the better materials for ovicidal use, but before field use of a material could be recommended, tests at low humidities would be advisable, particularly if the materials were to be employed for louse control in dry climates.

It is probable that humidity has a much greater effect on insecticides used in powder form than has previously been recognized. The marked effect of humidity obtained in the experiments described indicates that failures of other insecticides under certain conditions may be related to humidity. Further investigation of humidity and insecticidal activity is suggested in relation to eggs, larvae, and adults of various pests, especially where powders are used in their control.

SUMMARY.—Tests were undertaken in the laboratory to determine the effect of humidity on certain ovicidal powders for control of the body louse, *Pediculus humanus corporis* Deg. Sealed jars containing solutions of either salts or sulfuric acid were set up to maintain the desired humidity. Materials tested on 2-day and 6-day eggs included 1- and 10-per cent concentrations of phenothioxin, 3,5-dinitro-o-cresyl acetate, 2,4-dinitro anisole, 2,4-dinitro phenetole, methyl p-amino benzoate, azoxybenzene, 2,4-dinitro phenol, and tertiary butyl valone; 1 and 5 per cent concentrations of diethyleneglycol diester of chloracetic acid; a mixture of 1 per cent phenothioxin and 1 per cent 3,5-dinitro-o-cresyl acetate; and formula *MYL*. Results of these tests showed that the effectiveness of the materials depended upon the concentration of each material and upon the humidity. The mortality increased with an increase in humidity but this rise in effectiveness was not the same with all materials. A 10-per cent concentration of tertiary butyl valone was the only material effective at all humidities tested. Several of the powders were effective at humidities of 65 per cent and above. It was suggested that humidity may be an important factor in the effectiveness of other insecticides, particularly powders, against various insects and their eggs.—10-18-44.

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Dr. WM. A. RILEY RETIRES

Dr. Wm. A. Riley, Chief of the Division of Entomology and Economic Zoology at University Farm, St. Paul, Minnesota, retired on June 15, 1944. Dr. Riley served in this capacity from 1918 to 1925 and again from 1930 to 1944. During the interim period, 1925 to 1930, he was Head of the Department of Zoology on the Minneapolis Campus of the University of Minnesota.

Dr. Clarence E. Mickel was appointed Acting Chief of the Division on June 16, 1944.

Dr. Mykola Haydak has been appointed Associate Professor of Entomology at University Farm and succeeds the late Dr. Tanquary in charge of research and teaching in the field of Beekeeping.

Rotenone and Ox Warble Control

M. A. Stewart, *University of California, Berkeley*[1]

The economic importance of ox warbles, *Hypoderma lineata* (de Villiers) and *H. bovis* (de Geer) in beef and dairy cattle and the urgent necessity of their satisfactory control, resulting from present war-time demands, are too well recognized to warrant discussion here.

For a number of years warble infestations in dairy cattle have been controlled by several different methods; most satisfactorily by scrubbing over the swellings with a stiff brush dipped in a solution made up of 12 ounces of derris (5 per cent rotenone content)[2] in 1 gallon of water in which 2 ounces of soap had been dissolved. Due to the problems involved in handling range cattle, no satisfactory control method for ox warble infestations in these animals had been developed.

Preliminary Tests.—In February, 1941, investigations were initiated in an attempt to develop a satisfactory method of controlling ox warble infestations in range cattle. Since only *Hypoderma lineata* is known to occur in California, tests were limited to this species. However, there is no reason to believe that a chemical effective in killing *H. lineata* larvae will not be equally successful against *H. bovis*. Tests were conducted with the following sprays: (a) 1.5 pounds of wettable sulphur and 2.176 ounces of timbo in 15 gallons of water to which 2 cc. of a proprietary detergent was added; (b) 24 ounces of wettable sulphur and 10.88 ounces of timbo in 15 gallons of water to which 50 cc. of a proprietary detergent was added;(c) 24 ounces of wettable sulphur and 24 ounces of timbo in 15 gallons of water to which was added (1) 50 cc. of a proprietary detergent and (2) 40 cc. of detergent; and (d) 24 ounces of wettable sulphur and 24 ounces of timbo in 15 gallons of water. The detergent employed was a casein and a petroleum oil sulphonate, which is water soluble, substantially free from sulphonic tars, from other oil soluble matter, and from the petroleum and other like petroleum materials which might be injurious to tissues. The cattle used in the investigation, all of which were of approximately the same age and size and with approximately the same severity of ox warble infestation, were divided into five groups. One group of 9 animals was used as a control group and 4 groups of 18 animals each were used for testing the 4 different spray mixtures. Early trial tests demonstrated that a nozzle delivering a flat, fan-shaped spray provided much better penetration through the hair than a nozzle delivering a cone-shaped spray. Therefore, the former type of nozzle was used throughout the experimental tests. Each experimental animal was sprayed at a pressure varying from 250 to 300 pounds, with the nozzle held about 4 inches from the back of the animal. The spray was directed, as far as possible, against the grain of the hair and applied with a somewhat circular motion of the nozzle. Each experimental animal was sprayed once. Percentage of kill was determined by careful manual extraction of all grubs from both treated and control animals 10 days after treatment and immediate examination of these larvae to determine whether or not they were dead.

Because the above described experiments were started very late in the season, only preliminary results could be obtained. All the sprays tested gave excellent kill of grubs ready to emerge from the backs of the cattle. Comparable results against younger larvae were obtained only with the spray containing 24 ounces of wettable sulphur, 24 ounces of timbo and 50 cc. of detergent per 15 gallons of water. Relatively poor results in killing these younger parasites were obtained with sprays containing 2.176 and 10.88 ounces of timbo per 15 gallons of water. The spray containing 24 ounces of wettable sulphur and 24 ounces of timbo per 15 gallons of water gave significantly less kill of immature grubs than did the spray containing the same proportions of sulphur and rotenone but to which the detergent was added.

The differences in susceptibility to the various sprays between younger and more mature larvae, which is probably due to

[1] The author wishes to express his appreciation to Bernard Brookman, Norman Fraser and Newton Hardman for their valuable assistance in the routine conduct of the field tests.

[2] Derris and timbo used in all tests was of 5 per cent rotenone content.

the greater accessibility of the latter, is a matter of considerable import. The sooner the larvae in the backs of the animals can be killed, the less the resultant damage to the hides and the carcass wastage. Furthermore, the smaller the grubs are that must in part be absorbed following the lethal action of an insecticide, the less the physiological burden imposed upon the host.

Table 1.—Results of spraying cattle with 10 pounds of wettable sulphur, 10 pounds of derris (5 per cent rotenone content) and 1 pint of detergent in 100 gallons of water under a pressure of from 250 to 300 pounds.

	Fourth Stage Larvae		Fifth Stage Larvae	
	Alive	Dead	Alive	Dead
Treated 12/19/41				
Examined 12/27/41				
21 animals treated[1]	0	8	29	59
4 control animals	0	0	18	3
Treated 1/20/42				
Examined 1/23/42				
23 animals treated[2]	3	5	11	46
5 control animals	3	0	27	8
Treated 1/28/42				
Examined 2/3/42				
10 animals treated	10	5	19	45
Treated 2/23/42				
Examined 2/26/42				
10 animals treated	1	27	1	28
8 control animals[3]	12	3	9	13
Treated 3/28/42				
Examined 4/1/42				
20 animals treated[4]	5	6	41	72
5 control animals	0	0	8	5
Treated 3/31/42				
Examined 4/2/42				
6 animals treated[4]	0	2	0	8
5 control animals	0	3	2	2
Totals				
90 animals treated	19	53	101	248
27 control animals	15	6	64	31

[1] Three third-stage larvae: 1 alive.
[2] Two third-stage larvae: dead.
[3] One live third-stage larva.
[4] One dead third-stage larva.

ROTENONE–SULPHUR SPRAYS.—The following season, more extensive investigations were carried out. In table 1 are given the results obtained by spraying cattle as they were run through a chute, with 10 pounds of wettable sulphur, 10 pounds of derris and 1 pint of detergent in 100 gallons of water. The technique described in an earlier paragraph was employed.

The natural mortality of fifth stage larvae occurring in untreated animals was due almost entirely to failure of the grubs to emerge completely through the holes in the hides. The results obtained against third stage larvae were probably not significant because of the very small number of individuals exposed to the spray; but the results obtained against fourth and fifth stage grubs are considered significant and are sustained by careful field observations, without actual examination of all individual larvae, on more than 1500 head of cattle treated in the same way.

Table 2.—Results of spraying cattle with 10 pounds of wettable sulphur, 25 pounds of derris (5 per cent rotenone content) and 1 pint of detergent in 100 gallons of water under a pressure of from 250 to 300 pounds.

	Fourth Stage Larvae		Fifth Stage Larvae	
	Alive	Dead	Alive	Dead
Tested 1/28/42				
Examined 2/ 3/42				
10 animals treated[1]	3	10	6	30
Tested 2/23/42				
Examined 2/26/42				
10 animals treated	0	14	3	42
8 control animals	12	3	9	13
Totals				
20 animals treated[2]	3	24	9	72
8 control animals[3]	12	3	9	13

[1] No third-stage larvae found.
[2] Three third-stage larvae: all dead.
[3] One third-stage larva; alive.

During the above described experiments it was determined that approximately 2 quarts of spray are required per adult animal and that with 3 men crowding the animals into the chute and one man handling the nozzle, an average of 130 cattle may be treated in an hour.

Also during the season of 1941–42, tests were conducted with a spray composed of 10 pounds of wettable sulphur, 25 pounds of derris and 1 pint of detergent to 100 gallons of water to determine the relative effectiveness of a greater concentration of rotenone. The results are given in table 2.

A comparison of the results obtained by spraying with (a) 10 pounds of wettable sulphur, 10 pounds of derris and 1

pint of detergent to 100 gallons of water and (b) 10 pounds of wettable sulphur, 25 pounds of derris and 1 pint of detergent to 100 gallons of water, as given in tables 1 and 2, indicate that the latter mixture is the more effective. However, when the results of these two tests are weighted by giving consideration to the natural mortalities occurring in the control animals, one is again forced to disregard more or less the results obtained with the third stage larvae because of the small number involved, to consider the results with fourth stage larvae as definitely in favor of the higher concentration of rotenone, and to regard the differences in kill of fifth stage larvae as not being significant. Such results should be expected in view of the greater vulnerability of fifth stage grubs because of their greater degree of exposure to the chemicals. The greater cost of the more concentrated spray, however, probably does not warrant its use: particularly since it is necessary to repeat the treatments as long as larvae continue to appear in the backs of the animals (three sprayings are usually required), thereby ordinarily affording a second opportunity to kill the younger grubs.

Table 3.—Results of spraying cattle with 10 pounds of wettable sulphur, 5 pounds of derris (5 per cent rotenone content) and 1 pint of detergent in 100 gallons of water under a pressure of from 250 to 300 pounds.

	Fourth Stage Larvae		Fifth Stage Larvae	
	Alive	Dead	Alive	Dead
Treated 3/2/42 Examined 3/5/42				
12 animals treated[1]	6	7	12	14
5 control animals[2]	2	5	8	2

[1] Two third-stage larvae: alive.
[2] One third-stage larva: dead.

Wells (1942) stated that in the spray treatment of cattle for ox warble infestation very little is to be gained by using a spray more concentrated than 5 pounds of cube or derris powder containing 5 per cent of rotenone and 10 pounds of wettable sulphur to 100 gallons of water. In view of this claim, despite the poor results obtained in February, 1941 with dilutions of less than 10 pounds of derris per 10 gallons of water, tests were repeated in March, 1942 with this lower rotenone concentration, using approximately one gallon of spray per animal. The results obtained are given in table 3.

From the data presented in table 3, it is obvious once again that the number of third stage larvae dealt with is too small to yield significant results. However, from the other data in this table it is clear that 5 pounds of derris to 100 gallons of water is not comparable to 10 pounds of derris to 100 gallons of water in killing fourth stage larvae but is comparable to the latter in its effect upon fifth stage larvae. As pointed out in the earlier paragraph discussing the results of the February, 1941 experiments, this increased effect upon the fifth stage grubs should be expected because of their greater exposure to the chemical; but as also pointed out in the same paragraph, killing the younger larvae is a matter of considerable importance and the use of the spray with the greater rotenone concentration is entirely warranted, despite its slightly greater cost, because of the significantly greater benefits and savings thereby obtained. Therefore, the writer is not able to subscribe to the use of a spray for ox warbles which contains only 5 pounds of derris per 100 gallons of water, regardless of the fact that the ultimate reduction in heel fly population may be approximately the same.

ROTENONE WASHES.—As mentioned in an introductory paragraph, scrubbing over the swellings with a stiff brush dipped in a solution made up of 12 ounces of derris in one gallon of water in which 2 ounces of soap have been dissolved has been known for some time to be effective in killing cattle grubs. During the 1941–1942 season dairy cattle were scrubbed in this fashion with (a) one pound of wettable sulphur, one pound of derris and 0.1 pint of detergent in 10 gallons of water and (b) 10 pounds of derris and 0.1 pint of detergent in 10 gallons of water. The results of this experiment are given in tables 4 and 5 respectively.

Despite the small number of animals and the very light warble infestation reported in table 5, it is obvious from a comparison of this table with table 4 that scrubbing cattle with 1 pound of wettable sulphur, 1 pound of derris (5 per cent rotenone content) and 0.1 pint of detergent in 10 gallons of water does not con-

trol ox warbles, whereas the solution of 10 pounds of derris to 10 gallons of water plus detergent gives most excellent control. The failure of the former solution when scrubbed over the swellings with a stiff brush and its success when applied as a spray under 250 to 300 pounds pressure is probably due to the necessity, because of its lower rotenone concentration, of applying it with a strong driving force, thereby securing better penetration.

ROTENONE–SULPHUR DUST.—Laake (1942) has stated that equal parts by weight of wettable sulphur (325 mesh) and finely ground (200 mesh or finer) cube or derris powder containing 5 per cent rotenone applied as a dust is fully as effective as when derris and wettable sulphur are applied as a wash or spray. In the cattle grub season of 1942–1943 investigations were conducted on a dairy and a beef herd, each of 25 animals, in an attempt to corroborate the above statement. The results obtained showed that a powder composed of equal parts by weight of wettable sulphur (325 mesh) and finely ground (200 mesh) derris applied as a dust over warble swellings and gently rubbed into the hair with the palm of the hand is approximately as effective as spraying with (a) 10 pounds of wettable sulphur, 10 pounds of derris and 1 pint of detergent in 100 gallons of water or (b) 10 pounds of wettable sulphur, 5 pounds of derris and 1 pint of detergent in 100 gallons of water *only against fifth stage larvae*. The kill of third and fourth stage larvae by the application of this powder was entirely insignificant. Furthermore, the efficiency of the powder in killing fifth stage larvae was considerably below that of 10 pounds of derris in 10 gallons of water to which 0.1 pint of detergent was added and applied with a stiff brush as a wash. Therefore, the dust in question appears to have but a limited use.

Table 4.—Results of scrubbing dairy cattle with 1 pound of wettable sulphur, 1 pound of derris (5 per cent rotenone content) and 0.1 pint of detergent in 10 gallons of water.

	Fourth Stage Larvae		Fifth Stage Larvae	
	Alive	Dead	Alive	Dead
Treated 1/20/42 Examined 1/23/42 23 animals treated	2	3	43	0
Treated 2/23/42 Examined 2/26/42 5 animals treated	4	1	4	1
Totals 28 animals treated	6	4	47	1

Table 5.—Results of scrubbing the dairy cattle with 10 pounds of derris (5 per cent rotenone content) and 0.1 pint of detergent in 10 gallons of water.

	Fourth Stage Larvae		Fifth Stage Larvae	
	Alive	Dead	Alive	Dead
Treated 1/20/42 Examined 1/23/42 13 animals treated	0	1	0	5
Treated 2/23/42 Examined 2/26/42 3 animals treated	0	0	0	6
Totals 16 animals treated	0	1	0	11

OTHER CHEMICALS.—Because of the acute rotenone shortage consequent upon the present war, investigations were conducted during the 1942–1943 season in an attempt to find a substitute for this material to be used in ox warble control. Ground *Amorpha californica*, *Lethane* 384, *Lethane* 60, ethylene dichloride, trichloroethylether, dichloroethylether, 2,4, tertiary [butylphenoxy ethanol] and *Thanite* were tested. Each material was tried by adding 10 pounds of it to 10 pounds of wettable sulphur, 1 pint of detergent and 100 gallons of water and applying as a spray under a pressure of from 250 to 300 pounds. In no instance was a significant kill effected from any of these sprays.

During the 1943–1944 season another attempt was made to find a rotenone substitute. Twelve grams of a mixture composed of DDT 20 per cent, wettable sulphur 34 per cent, wetting agent 7.6 per cent and inert filler 38.4 was suspended in 500 cc. of water. Six cows moderately heavily infested with ox warbles were selected and 10 cc. of the above described suspension was introduced directly, by means of a syringe with the needle removed into the opening over each grub. Three days later the cattle were carefully inspected and none of the larvae treated was killed.

CONCLUSIONS.—Ox warble infestations in range cattle can be satisfactorily controlled by spraying under a pressure of 250 to 300 pounds, with a nozzle delivering a flat, fan-shaped spray, against the grain of the hair with 10 pounds of wettable sulphur, 10 pounds of derris, and 1 pint of detergent in 100 gallons of water. When the ratio of derris is raised to 25 pounds per 100 gallons of water the increased efficiency is not commensurate with the increased cost. When it is decreased to 5 pounds per 100 gallons, only fifth stage larvae are effectively controlled.

The effective spray described in the preceding paragraph is not satisfactory as a wash applied with a stiff brush over the swellings. At least 12 ounces of derris per gallon of water should be used in this type of treatment for ox warble infestations in dairy cattle.

A powder composed of equal parts by weight of wettable sulphur (325 mesh) and finely ground (200 mesh) derris applied as a dust over warble swellings and gently rubbed into the hair with the palm of the hand is effective only against fifth stage larvae.

Ground *Amorpha californica*, *Lethane 384*, *Lethane 60*, ethylene dichloride trichloroethylether, dichloroethylether, 2,4, tertiary [butylphenoxy ethanol], *Thanite* and DDT are ineffective against ox warbles.—7-8-44.

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Pyridine as an Attractant for the Mexican Fruitfly

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The most widely used lure for the Mexican fruitfly, *Anastrepha ludens* (Loew), has been fermented sugar solution (Baker *et al.* 1944). In some cases the sugar solution has not been inoculated with yeast but allowed to ferment spontaneously by wild yeasts which were present. McPhail (Baker *et al.* 1944) used dried beer yeast to produce a fermented sugar lure. He found this lure attractive enough to warrant considerable investigation regarding the attractive constituents. McPhail (1937) published the results of studies of some climatic factors affecting the number of males and females caught in a fermented sugar solution. Of several materials added to the fermented lure, pyruvic acid or its salt and sulfur were the only attractants worthy of mention.

The investigations of possible attractants for *Anastrepha ludens* have been continued. The yeast-fermented sugar lure has been used as a standard of comparison. Many compounds have been tested in the presence of the fermented control lure, either by suspending their alcoholic solutions in auxiliary vials (Ripley & Hepburn 1931) inside the traps or by mixing the solutions directly with the fermenting mixture. Any materials that might be found to be attractive under these conditions would have the advantage of the standard catch of the fermented lure in addition to the increase in catch due to the added attractant.

The various lures were compared with a control lure which consisted of 8 per cent of sucrose and 0.15 per cent of dried beer yeast. The sugar solution was allowed to ferment 1 or 2 days at about 25° C. During routine testing, the freshly prepared lure was inoculated with about 10 per cent of vigorously fermenting material, which ensured that the mixture would always be ready for use the following day. Vigorous uniform fermentation was obtained without sterilizing the medium. Fermentation continued 7 to 9 days at 25° C. The booster solutions were added after the control lure had fermented 1 day.

The tests were made with glass fruitfly

traps (McPhail 1943). Except where indicated otherwise, the traps were hung in mango trees in the vicinity of Cuernavaca, Morelos. Some comparisons were made in pairs with the positions of the test and control traps reversed during the following exposure period. Comparisons of several test lures with a control were effected through randomized location of the various traps. Each lure was tested in four to seven traps during a single exposure period. The statistics and designs of the trapping experiments will be described in detail in another publication. In the studies with pyridine, the comparisons were repeated a sufficient number of times to establish the significance of attractiveness of the compound.

The traps were placed from 10 to 20 feet up in the trees, using a bamboo pole fitted with a wire hook similar to the old lamp-lighters' technique.

Pyridine was found to be one of the most useful of the materials tested. It was tested in alcoholic solution in auxiliary vials, but it was found to be generally more effective when added directly as a booster solution for the fermented lure. Studies of the compound as an attractant have extended from 1941 to 1944.

The attractiveness of pyridine was first noted in the tests with auxiliary vials. With this technique there was no change in the fermented lure in the test traps. The vapor of pyridine mixed with the aroma of the fermentation. Homeopathic vials, 1.75 by 0.5 inch in size, were hung well up in the top of the trap so that the entrance was entirely unobstructed. The pyridine concentration was varied by diluting with alcohol, and 12 to 25 per cent by volume were attractive combinations. At first the most attractive solutions contained either iso-amyl alcohol or carbon disulfide along with pyridine and ethyl alcohol, but later tests indicated that pyridine was probably the chief attractive constituent.

The trap data in table 1 have been combined for various seasons during which the attractiveness of the pyridine was approximately the same. The increase due to pyridine in the vial was based on a comparison of paired traps both containing the control lure. Any differences must have been due to the material in the vials. The minimum significant difference ($P = 0.05$) was estimated as 15 per cent for 30 trap exposures. The period of exposure ranged from 3 to 5 days, with the longer exposures during the seasons of lower population.

The data in table 1 indicate that the mixtures containing pyridine were relatively more attractive in May than at any other season during which tests were made.

Table 1.—Attractiveness to *Anastrepha ludens* of pyridine in auxiliary vials in the presence of yeast-fermented sugar solution at Cuernavaca, Morelos, Mexico.

Season	Pyridine Trap Exposures	Fruitflies Caught in Pyridine Traps		Increase Due to Pyridine[1]
		Per Trap per Day	Total	
	Number	*Number*	*Number*	*Per Cent*
May 1941	40	32.2	4514	98[2]
June 1941	60	18.0	3502	10[2]
June 1941	30	18.5	2030	23
December 1941–January 1942	56	10.3	2663	26[2]
December 1941–January 1942	56	9.8	2537	20

[1] Pyridine was tested at 12 or 25 per cent by volume in alcohol. Alcohol alone tested in the auxiliary vials gave no appreciable increase.

[2] The pyridine solutions contained from 6 to 25 per cent of either iso-amyl alcohol or carbon disulfide, but neither seemed to affect the attractiveness very much.

Pyridine was then added, in alcohol, directly to the fermented lure as a booster solution. It was found that the fermentation continued vigorously, even in the presence of small amounts of alcohol and pyridine. Several concentrations of pyridine and alcohol were tested as boosters for the fermented lure. The addition of 0.1 or 0.2 per cent of pyridine to the control lure generally increased the catch. The results of three experiments during April and May 1942 were averaged and are presented in table 2. An experiment during March 1943 with a wider range of concentrations of pyridine was also included.

The amount of alcohol added to the lures listed in table 2 ranged from 0.4 to 1.6 per cent, but experiments during the warm weather indicated that the addition of small amounts of alcohol have little effect on the catch from the fermented lure. Quantities approximating those men-

Table 2.—The effect of the concentration of pyridine in the yeast-fermented sugar lure on the catch of *Anastrepha ludens* at Cuernavaca, Morelos, Mexico.

Concentration of Pyridine[1]	*A. ludens* Caught per Trap per Day	
	April–May 1942	March 1943
Per Cent	*Number*	*Number*
0	5.9	3.5
0.05	8.8	3.6
.1	13.8	6.1
.16	11.0	—
.2	11.0	3.4
.33	12.0	—
.4	16.7	5.5
1.0[2]	—	5.1

[1] Added as 10 or 20 per cent alcoholic solutions.
[2] Added as 50 per cent alcoholic solution.

tioned above are produced by fermentation under favorable conditions. During the winter the temperatures are low enough to retard the fermentation in the traps and the addition of alcohol may increase the catch. The effect of alcohol was studied by adding it to the fermented lure containing 0.1 or 0.2 per cent of pyridine in Cuernavaca during the winter, when the average monthly mean temperature is between 18° and 19° C. At the same time some similar experiments were made at Cocoyotla, which is about 1400 feet lower and approximately 3° to 5° warmer. Table 3 gives a summary of the results.

During the cool weather in Cuernavaca the addition of 0.1 per cent of pyridine and 1.0 per cent of alcohol gave an increase of 69 per cent in the catch of fruitflies over that of the control lure. This was greater than that of the other mixtures. The addition of the alcohol yielded a significant increase. At Cocoyotla, with higher temperatures, the three lures containing pyridine were of nearly the same effectiveness, showing an average increase of 37 per cent.

Table 3.—The effect of alcohol and pyridine added to fermented control lure on the catch of *Anastrepha ludens* in two localities of Morelos, Mexico. January and February 1944.

Pyridine Added	Alcohol Added	*A. ludens* Caught per Trap per Day— Cuernavaca, 5000 ft. on Mangoes	Cocoyotla, 3600 ft. on Oranges
Per Cent	*Per Cent*	*Number*	*Number*
0	0	6.2	3.3
0.1	0	8.7	4.3
.2	0	8.0	4.8
.1	1.0	10.5	4.5
.2	1.0	7.9	—

The available data were combined to show the increase in catch due to the addition of 0.1 or 0.2 per cent of pyridine to the fermented lure. Alcoholic solutions of 10 or 20 per cent of pyridine by volume were added. Most of these tests were made with a random distribution of the traps throughout the mango grove. The minimum significant difference ($P=0.05$) for the data in table 4 was estimated as 15 to 19 per cent. The period of exposure ranged from 1 to 4 days.

Again pyridine was relatively more attractive to *Anastrepha ludens* during April and May, which are the warmest months in Cuernavaca. This seasonal effect has been observed in two different years. The catch of *A. ludens* gradually decreased from a maximum late in April to the first part of July. The pyridine was most efficient during the time the green mangoes were abundant, which suggests the possibility that while the traps are competing with the attractive green fruit the fruitflies may be more selective than at other times in their reactions toward various lures.

Table 4.—Effect of pyridine in a booster solution for yeast-fermented sugar lure on the capture of *Anastrepha ludens* at various seasons at Cuernavaca, Morelos, Mexico.

Season	Pyridine-Trap Exposures	Fruitflies Caught in Pyridine Traps		Increase in Catch Due to Pyridine[1]
		Per Trap per Day	Total	
	Number	*Number*	*Number*	*Per Cent*
April–May 1942	102	15.2	3,015	143
June–August 1942	90	75.1	8,410	52
June–August 1943	108	24.7	5,666	23
February–March 1943	84	6.9	1,984	58
January–February 1944	252	8.6	6,509	33

[1] The concentration of pyridine added to the fermented lure was 0.1 to 0.2 per cent.

The relative attractiveness of the control lure containing pyridine was tested in various kinds of trees. The data in table 5 gave a comparison between mango, citrus, and "black sapote," *Diospyros ebenaster* Retz., all in the same garden near Cuernavaca, Morelos. More *Anastrepha ludens* were caught in the black sapote than in the mango trees, but appar-

Table 5.—Comparison of the attractiveness to *Anastrepha ludens* of pyridine in various types of trees at Cuernavaca, Morelos, Mexico.

Date, May	Mango		Citrus[1]		Black Sapote	
	Flies per Trap per Day	Increase Due to Pyridine	Flies per Trap per Day	Increase Due to Pyridine	Flies per Trap per Day	Increase Due to Pyridine
	Number	*Per Cent*	*Number*	*Per Cent*	*Number*	*Per Cent*
12–16	23.8	369	1.7	267	59.0	151
16–21	18.7	211	1.1	211	53.9	65
21–25	—	—	3.6	92	91.4	5
25–29	—	—	3.3	65	81.9	10

[1] Grapefruit and sour limes. The trees were only about 8 feet tall and did not provide very good shelter for flies.

ently the flies were less selective in choosing the more attractive lure. Earlier studies had also shown that more fruitflies were caught in the black sapote mingled with mango than in the mango trees themselves, even though the black sapote is not a host fruit for *A. ludens*.

The pyridine booster solution gave approximately the same increase in citrus and in mango trees. A similar result was obtained by comparing increases observed in Cuernavaca mango and Cocoyotla orange trees (table 3). The increases were 33 and 37 per cent, respectively. Other tests at Cocoyotla gave an average increase of 42 per cent in July 1942 and 1943, which might be compared with increases of 23 and 52 per cent for mangoes in Cuernavaca during similar periods.

A good grade of pyridine, which boiled at 113.5°–115.5° C., was used in all the experiments. It was obtained from an organic chemical supply house at a cost of $4.50 per kg., which means an expense of 45 cents for 0.1 per cent of pyridine added to 100 liters of lure. The attractiveness of the cheaper grades of pyridine has not yet been studied.

Summary.—Pyridine in alcohol solution increased the attractiveness of yeast-fermented sugar lure for *Anastrepha ludens* when added directly or when tested in auxiliary vials. From 12 to 25 per cent of pyridine by volume was used in the vials. The amounts of pyridine added were generally 0.1 or 0.2 per cent, but as much as 1.0 per cent was attractive. The amount of alcohol added was about 1 per cent of the lure.

Studies were made in two localities of different altitude and climate.

The attractiveness of the lure showed a distinct seasonal effect. The increase due to pyridine was 98 to 143 per cent in April and May but only 10 to 58 per cent in other seasons. During the winter months the best combination tested was 0.1 per cent of pyridine and 1.0 per cent of alcohol, but during warm weather the addition of alcohol made little difference.

There was little difference in the efficiency of pyridine in citrus and mango trees. In black sapote trees, *Diospyros ebenaster* Retz., where the average fruitfly catch was greatest, there was the least increase due to pyridine.

The cost of the pyridine was 45 cents for 100 liters of the lure.—8-22-44.

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Professor Ruggles in Alabama

The many friends of Professor Ruggles who have not heard from him recently will be interested to know that he is doing some farming at Union Springs, Alabama. He writes that he is caring for some livestock and doing some gardening as well as planting an orchard. Also that he "is lost to the profession of entomology," a statement which we will scarcely be willing to accept literally. Professor Ruggles is living with his son.

Control of the Filbert Worm and Filbert Weevil by Orchard Sanitation[1]

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In the course of studies of the filbert worm, *Melissopus latiferreanus* (Wlsm.), and certain weevils, chiefly *Curculio uniformis* (Lec.), in the Pacific Northwest, investigations have been made of their possible control by picking up the nuts that dropped prematurely, before the worms in them could complete their development. During the preharvest season, when summer temperatures prevail, the *Melissopus* worms feed voraciously, complete their larval development in about 20 days, then bore their way out of the nuts to seek places for hibernation. They usually hibernate in tough, impervious cocoons within the first 2 or 3 inches of soil, but occasionally in rolled leaves or other suitable trash on the ground. The larva of the filbert weevil requires only a few more days for maturing than does the filbert worm. Some weevil larvae complete their development before harvest time, issue from the nuts, form their cells some 10 inches or deeper in the soil, and hibernate there for 2 or 3 years.

The filbert grower need have no serious concern regarding the disposal of the worms in the mature crop, because as soon as these nuts are harvested they are transported to the processing plant, where the wormy nuts are sorted out and destroyed, worms and all. That source of the potential reinfestation of his orchard is thereby eliminated, unless the mature nuts are allowed to remain on the ground an undue length of time. The other and more dangerous source is the infestation in the nuts that drop prematurely.

At the outset of the work on the filbert worm in 1937 it seemed desirable to include in the program a study to determine the ratio of infestation in the nuts that drop prematurely to those in the final crop together with the number infested in each group. Beginning in 1938, therefore, an accurate record was kept of the total yield of certain designated trees in different localities in the principal filbert-growing areas of the Pacific Northwest, only 16 of the more important of the numerous varieties of filbert being included in the study. The results of these studies are presented in table 1. It will be noted that 606 filbert trees produced a total of 896,195 nuts in 6 years, of which only 15.3 per cent dropped from the trees during the pre-harvest season. It is a significant fact that this small proportion of the total yield included a few more wormy nuts than those gathered in the harvest. In the above total of 896,195 nuts are included, by actual count, 35,890 infested ones, of which 18,198, or slightly more than half of the wormy nuts found during the 6-year period, were among those that dropped from the trees prematurely.

Table 1.—Comparison of the infestation by the filbert worm in the pre-harvest drops and the harvested nuts for the years 1938, 39, 40, 41, 42 and 43.

	Preharvest Drops		Harvested Nuts	
Trees	Total	Infested	Total	Infested
Number	*Number*	*Per Cent*	*Number*	*Per Cent*
229	35,928	14.3	176,675	3.0
127	35,807	6.2	180,284	.7
72	16,352	9.5	61,233	2.0
65	14,720	14.8	132,106	2.3
67	22,444	22.7	108,710	4.1
46	12,166	16.4	99,770	2.4
Total	Total	Average	Total	Average
606	137,417	—	758,778	—
—	—	13.2	—	2.3

The results shown in table 1 are in substantial agreement with preliminary results reported earlier (Dohanian 1940). Although these experiments were intended primarily to yield information on the filbert worm, work in subsequent years indicates that much the same situation exists with reference to the filbert weevil.

From the beginning of the study it became apparent that the periodic gathering and the immediate destruction of the preharvest drops would considerably reduce the worm hazard. In 1942 an experiment was therefore started in a filbert orchard covering 5.75 acres near Eugene, Oregon. The owner of the orchard had his regular

[1] From the Program of the Pacific Slope Branch, June 1944.

farm hands gather the dropped nuts on August 3, and at 10-day intervals thereafter, keeping the different varieties in separate gunny sacks. The gathered drops were brought to the laboratory at Eugene, where each sackful was weighed, then the nuts were emptied into large, shallow, rectangular boxes, and 15 or 20 per cent of them were removed for examination. These sample lots were taken, a handful at a time, from different parts of the box in the attempt to make them typical and representative of the entire lot. The nuts were then cracked and a record made of the infestation, all larvae found, either living or dead, being recorded as to species. When nuts had holes in the shell and the kernels had been largely consumed it was assumed that the larvae, being full-fed and full-grown, had left the nuts for hibernation. In such cases the worms were classified as being "in hibernation," since under actual farm practice of orchard sanitation they would have escaped destruction before the nuts were picked up and burned.

The results of the experiment in 1942 warranted its continuance in 1943. Again the same procedure was followed, with one exception. In order to ascertain whether more frequent collection of the premature drops would result in the removal and consequent destruction of a larger number of worms, the interval between collections was reduced from 10 to 7 days. The results of the two seasons' work are presented in table 2.

Taking the 2 years together, only 5 to 7 per cent of the larvae present in the premature drops were able to escape, therefore the population that would otherwise have remained in the orchard was reduced about 94 per cent. In the case of the filbert worm, there was an improvement in the results the second year by reason of the shorter intervals between successive pick-ups.

Table 2.—Computed number of *Melissopus latiferreanus* and *Curculio uniformis* larvae in the preharvest drops in 1942 and 1943, and the percentage of worms destroyed in the orchard-sanitation experiment.

Species	Nuts Infested		Larvae—					
			Dead	In Nuts	That Left Nuts	Total Living	In Hibernation	Destroyed
	Number	*Per Cent*	*Number*	*Number*	*Number*	*Number*	*Per Cent*	*Per Cent*
M. latiferreanus:								
1942	2,313	3.5	361	1,690	262	1,952	13.4	86.5
1943	1,574	1.3	396	1,097	81	1,178	6.9	93.1
C. uniformis:								
1942	3,277	5.0	755	2,472	50	2,522	2.0	98.0
1943	767	.6	44	711	12	723	1.7	98.3
Total:								
1942	5,590	—	1,116	4,162	312	4,474	7.0	93.0
1943	2,341	—	440	1,808	93	1,901	4.9	95.1

Total premature drops: 1942, 65,350; 1943, 119,338.

The cost of picking up the drops was surprisingly low—only $2.92 per acre for picking up the drops four times in 1942, and $7.18 per acre for picking them up seven times in 1943. The nuts that drop prematurely are very easily gathered because they fall in clusters and are retained in the shucks. These clusters are readily seen on the ground, which is clean-cultivated at that time of the year. The cost of removing the premature drops compares very favorably with that of spraying.

Studies of the susceptibility of the different filbert varieties to attack by the several worms found infesting the nuts indicated decided preferences for certain of the varieties. The two insects discussed in this paper strongly favored some of the pollinizers, particularly the very common variety Daviana. The filbert worm has invariably shown preference for the Daviana in the ratio of 3:1, as compared with the important commercial variety Barcelona. The filbert weevil has manifested even a greater liking for the Daviana, four times as many nuts of this variety having been found infested by the weevil during

the years 1938–43 as the combined infested total of the remaining 15 varieties studied during those years. From the point of view of insect injury it is probably fortunate that, in general, the pollinizers bear much fewer nuts than the commercial varieties. Since the filbert crop is harvested by hand picking the individual nuts from the ground, practically all growers follow the practice of allowing the nuts under the pollinizing varieties to remain unpicked until the very last, or until the accumulation of a sufficient quantity to make it profitable for the pickers to work. (Pickers are usually paid at a given rate per pound of nuts picked.) This procedure has been one of the chief reasons for the gradual increase in infestation, once the insects have become established in an orchard. Although gathering and burning of the drops during the preharvest season only once a week seems adequate to keep the infestation at a minimum in normal seasons, growers are advised that more frequent picking of the drops under the pollinizers, specially the Daviana—the variety most favored by all of the kernel-infesting worms—is strongly urged. Even the daily picking of the crop of this variety and its prompt removal from the orchard is suggested as a further substantial aid in the reduction of potential future infestations.

It is also possible to use hogs for removing the premature drops, thus avoiding the trouble and expense of picking them up. That has been done by a filbert grower of Gervais, Ore. Among the filbert plantations operated by this farmer is a 6-acre plot which was 18 years old in 1943. (Infestations are rare or extremely light in plantations under 10 years of age, but tend to increase as the orchards grow older.) For several years some of the nuts produced here have been wormy. No deductions have been made, however, by the nut-processing plant for excessive percentages of wormy nuts during the last 5 years, apparently because each year this grower has allowed about 18 pigs to graze in this plot, which is fenced in, from the time the first premature nuts began to drop until the first fall of mature nuts. The pigs ate not only the kernels, if any, that may have been in the nuts but the worms as well. Since the pigs crack all nuts, they feed on, any worms escaping are doomed, for they are still immature and have practically no chance of completing their development once they have been removed from the kernels, which provide their nourishment.

Filbert growers considering the use of orchard sanitation for the control of insects feeding in the kernels of the nuts should bear in mind that the effects of the work will not be fully evident until the third or fourth year after it is started. Any reduction in the population of the filbert worm should be evident the year after the drops are first picked up, but in the case of the weevils, which have 2- or 3-year life cycles, at least 2 years must elapse before any benefit can be anticipated. From that time on an increasing cumulative benefit should be realized, unless there are present nearby abundant sources of reinfestation. In such circumstances it is indeed imperative that a grower continue to practice orchard sanitation with even greater persistence.

Another reason for considering orchard sanitation as a means of controlling these insects is the absence of an effective insecticidal treatment for the filbert weevil. Spraying with lead arsenate has been reported (Thompson 1942) as effective in the control of the filbert worm, but not all growers have yet adopted spraying as a standard practice. Under present wartime conditions, the adoption of available insect-control methods that will conserve insecticides for use against insects not otherwise controlled is especially desirable, particularly when such practice is less expensive than the application of insecticides.—7-3-44.

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Effect of Cultural Practices on the Citrus Rust Mite

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In the southeastern states many citrus growers and some experimental workers are of the opinion that the citrus rust mite, *Phyllocoptes oleivorus* Ashm., is ordinarily less abundant on citrus trees growing in a cover crop than in groves otherwise similarly situated and cared for but without a cover crop. These opinions seem to be based on observations and, so far as is known, there is no published experimental evidence to prove that a real difference exists, although several rather logical arguments have been advanced. One theory is that parasites and, especially, fungi that attack the rust mite flourish under humid conditions and that the relative humidity in a grove in cover crop is higher than in one kept clean-cultivated. It has been stated that a growing cover crop gives off considerable moisture and also protects the soil surface from the sun, reducing the reflection of heat from the ground and permitting less evaporation from the soil, which results in an increase in relative humidity. The species of plant making up the cover crop is not considered important, but it is generally agreed that one that grows tall, as the crotalarias do, and covers the ground completely making a dense covering, is the most desirable.

If the growing of a cover crop is an important factor in controlling the rust mite and this cultural practice could be put more generally into effect, fewer applications of sulfur would be needed and the result would be a saving in money ordinarily expended for insecticides. In an effort to accumulate more definite information on the effectiveness of a cover crop for rust mite control, preliminary experiments on orange trees in St. Lucie County Fla., were conducted in 1940 and 1941, and more extensive experiments in 1942 and 1943.

EXPERIMENTAL PROCEDURE.—The experiments were carried on in an orange grove that was 5 years old in 1940. In 1940 the experimental arrangement consisted of only 1 plot of approximately 6 by 14 trees (about 1 acre) in a cover crop, and a similar adjacent plot which was kept clean-cultivated. In 1941 the experimental set-up was expanded, and 2 additional plots, each of the same size as those used in 1940, were made available. In this way each treatment, cover-cropping and clean culture, was replicated. In 1942 the arrangement was expanded still further and 4 replications of each treatment, each on a plot of about an acre, were available. The same plots were used in 1943, but the treatments were reversed so that the areas that had been in cultivation during 1942 were in cover crop during 1943. Throughout the entire period no two adjacent plots received the same treatment, and the trees selected for sampling were always located well within each plot so as to receive the maximum influence of the particular treatment.

Cover crops are rather easily maintained during the summer in the east-coast section of the citrus area in Florida, and volunteer vegetation, consisting largely of the crotalarias, was utilized in 1940 and 1941. Crotalaria seed of the varieties *intermedia* and *spectabilis* were sown for a cover crop in 1942 and 1943. The clean culture was accomplished by disk-cultivating one way between the trees and immediately repeating the operation at right angles. Each cultivation was followed with hand-hoeing around individual trees to eliminate vegetation impossible to reach with the disk without injury to trees. Usually 5 thorough diskings and hoeings at intervals during each season were sufficient to keep the plots clean. In fact, after the first cultivation the succeeding ones followed before very much growth became established. In 1940 and 1941 the first cultivations were performed in May; in 1942 and 1943, in March and January, respectively. The experiments did not extend beyond October in any year, because by that time the cover crop was ripening and drying and, unless disked into the soil, would have become a serious fire hazard. (Fig. 1.)

The rust mite is small, and individuals cannot be seen without the aid of a magni-

[1] Acknowledgment is made of the assistance of Minter DuPree.

fying lens. A linen tester having a field ½ inch by ½ inch was used in determining infestations. In 1940 and 1941 observations were made by counting the number of mites in this field on the top surfaces of 10 leaves, on the lower surfaces of 10 different leaves, and on the surfaces of 10 fruits on each tree designated for sampling. In 1940 infestation data were based on the total number of mites found on 30 such "squares" from each of 12

FIG. 1.—Clean-cultivated and cover-crop areas in the experimental orange grove, St. Lucie County, Fla., 1940–43.

trees, or 360 squares per treatment; in 1941 the data were taken from 20 trees, or a total of 600 squares per treatment. Sampling studies conducted during 1940 and 1941 showed that counts of mites on the lower surfaces of leaves provided a more accurate estimate of infestation than counts on the upper surfaces or on fruit surfaces, and in 1942 and 1943 observations were made on the under surfaces of 10 different leaves per tree, and from 40 trees, or a total of 400 squares per treatment. During the four seasons counts for each treatment were ordinarily made at monthly intervals following the first cultivation until just before the mowing or disking of the cover crop in the fall.

During 1942 and 1943 hygrothermographs and maximum and minimum thermometers were operated in one plot of each of the two treatments. Before being installed in U. S. Weather Bureau shelters, the machines were adjusted under the same conditions, so that they would record as nearly alike as possible.

The trees selected for examination in the plots of both treatments were sprayed with lime-sulfur in January 1942, to equalize any difference in mite infestations that might have been caused by the previous season's experiment, and the same trees were dusted with sulfur in January 1943 for the same reason. No other rust mite-control measures were applied to these trees during 1942 or 1943.

RESULTS.—In 1940, although the data on rust mite infestation obtained from month to month for each treatment showed very slight differences, it was realized that to obtain more conclusive information a more extensive field set-up, to include replications of treatments, would be necessary, and therefore the treatments for the work in 1941 were replicated. Difficulty was experienced that year in keeping the trees designated for clean culture free from a cover crop, because continued wet weather during the summer months prevented cultivation. However, the experiments were carried on successfully in 1942 and 1943, and the data obtained during those two seasons are presented in table 1.

Although the accumulation of data was started shortly after the experiment was begun in each of the two seasons, the cover-crop treatment should not have begun to influence mite infestations, if a cover crop really does affect their abundance, until June or July, when the vegetation had reached its maximum height and density.

In the 1942 data a comparison of the infestations found in April shows more mites on the trees growing in a cover-crop plot than on those in the clean-cultivated plot, but the reverse was true in May and June. In July and August fewer mites, and in September and October more mites, were found on trees on the cultivated areas than on those on the cover-crop areas. In 1943 more mites were found on the clean-cultivated trees from March through June, fewer in July, and a greater number in August and September, than on trees in a cover crop. The infestation data taken on each date during the 2 years were analyzed statistically by the analysis-of-variance method, and no significant differences at the 5-per cent level between infestations were found in the two treatments on any one date. On several dates during the two seasons large differences in the numbers of mites in the plots for the two treatments were found, but these

differences were not caused by the treatments. Sampling studies have shown rust mite populations to be exceptionally variable in either heavy or light infestations. In general, less variation is associated with heavy infestations than with light ones, but this is not always true.

Infestations in the case of both treatments were much heavier in 1942 than in 1943, especially in the early part of the season. No explanation can be given for the difference in the number of mites found during the two seasons, because the data were taken from the same trees during the two seasons and all the trees used for counting purposes were treated alike, except for the clean-culture and cover-crop treatments.

Table 1.—Citrus rust mites on orange trees, St. Lucie County, Fla., 1942–43.

Year	Plot	Rust Mites on 400 Half-Inch Squares per Treatment								
		March	April	May	June	July	Aug.	Sept.	Oct.	Average
		No.	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*
1942	Clean-cultivated	—	164	422	218	91	321	325	185	246.5
	Cover-crop	—	263	384	133	168	357	266	162	247.5
1943	Clean-cultivated	4	15	29	45	40	130	84	—	49.5
	Cover-crop	1	1	0	10	51	56	64	—	26.1
Average:										
	Clean-cultivated	—	89	225	131	65	225	204	—	156.5
	Cover-crop	—	132	192	71	109	206	165	—	148.5

EFFECT OF CULTURAL PRACTICES ON TEMPERATURE AND RELATIVE HUMIDITY.—In 1942, during the period June through September, the mean maximum temperature in the clean-cultivated plot was 88.6° F., as compared with a mean maximum of 87.6° in the cover-crop plot, or a mean maximum 1 Fahrenheit degree higher in the clean-cultivated than in the cover-crop plot. During the same period the mean minimum was 69.7° in the cultivated and 69.3° in the cover-crop plot. The maximum relative humidities in the cover-crop plot averaged about 2 per cent more than in the clean-cultivated plot, and the minimum relative humidities averaged about 2 per cent greater in the cover-crop plot. The temperatures and humidities recorded in the two treatments were so similar that it was thought the small variation might have been in the recording instruments and not due to the treatments; therefore, in 1943 the instruments that had been in the cover-crop plot were placed in the clean-cultivated plot, and vice versa, the same locations being used as had been employed in the previous year.

During the same period in 1943 the mean maximum temperature was 88.5° F. in the clean-cultivated plot and 89.0° in the cover-crop plot, or 0.5° higher in the latter. The mean minimum was 71.2° in the clean-cultivated plot and 70.1° in the cover-crop plot, resulting in a mean minimum 1.1 Fahrenheit degrees higher in the clean-cultivated plot. The maximum relative humidity averaged about 2 per cent more in the clean-cultivated plot than in the cover-crop plot, and the minimum relative humidity also averaged 2 per cent more in the clean-cultivated plot. The temperatures and humidities recorded in both plots during 1943 differed to about the same extent as in 1942; but in some instances the results were reversed, so that in the plot in which the temperatures and humidities were higher in 1942 they were lower in 1943, indicating that some of the variations during the two seasons were due to the machines used. The differences, however, were so small that even if they were real it is evident that the cultural treatments had very little effect on temperature and humidity, and very little effect on the numbers of parasites and the amount of fungus that would be expected from them. There was no indication during this work that rust mites were being attacked by parasites or fungi in either the clean-cultivated or the cover-crop plots.

EFFECT OF CULTIVATION ON TREES.—The intensive cultivation required each season to maintain plots in a condition of clean culture stimulated the trees considerably. They put on more growth, developed more green leaves, grew larger, and generally appeared to be in better physical condition than uncultivated trees, even though there was some evidence that the cultivated trees were more heavily infested with the Florida red scale, *Chrysomphalus aonidum* (L.), than were the uncultivated trees.

SUMMARY.—A comparison has been made of the numbers of the citrus rust mite, *Phyllocoptes oleivorus* Ashm., found on orange trees growing in clean-cultivated plots and on those grown in plots having a cover crop. There was no difference in rust mite infestation between trees growing under these two conditions. There were very small differences, however, between the temperatures and humidities recorded under the two treatments. The cultivation employed to obtain clean culture stimulated the trees subjected to this treatment each season so that they were more vigorous and in better physical condition than were those in the cover-crop areas. There was some evidence that the cultivated trees were more heavily infested with the Florida red scale, *Chrysomphalus aonidum* (L.), than were those in the cover-crop areas.—7-31-44.

Adult Observation Stations to Determine Effectiveness of the Control of *Anopheles quadrimaculatus*

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The chief means of evaluating the effectiveness of a marlaria control program conducted on the vector control basis is by means of adult observation stations. This is made possible by the fact that anopheline species fly into shelter during or at the end of their nocturnal activity and remain there throughout the daylight hours. Therefore the selection of a number of diurnal resting places, and a single weekly observation of the adult population therein, will yield a week by week population density comparison which will give an accurate picture of the effectiveness of the control measures. Larval inspection by the testing of breeding places for anopheline larvae can also serve as a criterion, but adult counts are more reliable and efficient. It is true, of course, that dipping is the only definite method of determining that the malaria mosquito, *Anopheles quadrimaculatus* Say is breeding in a particular body of water. On the other hand, adult counts are an index to a wider area than larval inspection, serve as a check on larval testing, and are concerned with that stage of the mosquito which actually transmits the disease. The two types of inspection must be utilized on any anopheline control program, but in so far as a criterion for effectiveness of operations is concerned, adult counts are the better indices.

In order to utilize adult counts to the best advantage, it is necessary to select diurnal resting places which give a true index to the anopheline population. A poor adult station is worse than none since the results obtained give a false impression of the conditions present. The purpose of the following discussion is to list and consider comparatively the various types of adult stations and their organization as used during the past four years on the Malaria Control Program in North Carolina. During this period inspection work has been carried out in more than fifty localities in the state ranging from Elizabeth City to Wilmington and west to Asheville. In twenty-six of these projects, organized weekly adult and larval inspections have been in operation during the mosquito breeding season. All subsequent material should be considered in the light that it has been derived from a "working" malaria mosquito control program, a purely practical aspect with no research phases involved.

The writer has observed that in many discussions of the relative merits of different types of stations there is a great tendency to speak freely on the value of a cer-

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tain type of station without considering that station as regards its present use, its location in proximity to breeding grounds and the intensity of breeding therein, or the prevailing ecological factors. For example, the privy is stated to be an excellent indicator by one individual, yet another contends it is of little value. Both may be right in the particular cases each is thinking of. A privy exposed to direct sunlight one-half mile from any appreciable breeding may never show many anopheline mosquitoes while another in the shade 300 feet from an anopheline breeding pond or adjacent to a pigpen will yield high counts consistently. Consequently, no categorical statement as to the virtues of one type or the other is advisable.

Adult resting places can be separated into two categories, baited and non-baited. In the first may be placed dwellings, animal sheds, and privies while the second includes culverts, bridges, nail kegs, light traps, hollow trees, and anopheline houses. As is evident, the distinguishing characteristic for the two types is the absence or presence of a host. Another classification frequently used divides adult stations into two types, natural and artificial. Under the latter are included boxes, nail kegs and anopheline houses, all other types being termed natural. It is difficult, however, to see why an anopheline house placed in a swamp is any more artificial than a culvert under a road or a privy in the same swamp. Under this second system, no clear-cut character distinguishing the two types is evident, and it is difficult to classify definitely some types of resting places.

In practice, it should be kept in mind that a non-baited shelter such as an anopheline house, if placed adjacent to a pig sty, is for all entomological purposes an animal shelter.

When an adult station is in the middle of, or in the immediate vicinity of, a good breeding area, it apparently makes little difference what type of station is employed. From the writer's observation, any shelter will do. It is true that baited stations, particularly animal sheds, will show higher counts, but non-baited resting places will have sufficiently high counts to permit density evaluations on a week-to-week basis. It is only when the adult station is some distance (500 ft. or more) from the breeding place that the relative values of the different types of stations are easily discernible.

Generally speaking, the value of baited shelters in comparison to non-baited ones is much greater as the distance between breeding areas and the station increases. Adjacent to breeding area all types of stations show the presence of *Anopheles quadrimaculatus*, but as the flight distance grows, the non-baited shelter populations decrease sharply with those of baited shelters (animal sheds), remaining relatively much higher. Subsequent discussion is on the basis of adult stations 500 feet or more from good breeding areas unless otherwise stated.

BAITED STATIONS.—*Dwellings.* If all factors were to be equalized, this type of station would be the best indicator of the effectiveness of a malaria mosquito control program since it samples the "*quadrimaculatus*" population which is actually in close contact with the people. However, several factors enter in; there may be objections from the owner, many houses are screened, resting areas in the houses are varied and require much time for close inspection, and anti-mosquito practices may be used by occupants. Consequently, a dwelling is rarely used as an adult station unless data from that source are particularly desired.

Animal Shelters. No host preference differences between cow, horse, pig, goat or chicken have been clearly evident although chicken houses generally are less productive than shelters of the other animals. A suitable shelter over any one of the first four mentioned animals has been found satisfactory

Differences in host behavior and the type of shelter available are factors which probably influence the use of different animal shelters more than host preference. Cows frequently remain in pasture at night and sudden decreases in adult anopheline counts may be due to this rather than to control methods. Pigs are best in this regard since they usually remain closely confined, but their shelters generally are much less satisfactory than horse or cow sheds.

It is generally considered that suitable animal stations must be cool and dark with little wind, but observations have revealed that frequently this is not the case. Malaria mosquitoes many times are found at the lighter end of a stable rather

than in the darker portions. Likewise, hot and open stables are frequently satisfactory. The best criterion upon which to base selection of a stable is to visit it and let the adult counts be the yardstick.

The most satisfactory shelters employed have been small, one or two animal sheds with 8- or 9-foot ceilings. Such stations are easy to check and they reduce to a minimum the chance of overlooking a resting place. It has been the policy to discard any animal shelter once the animal is removed, since observations following the loss of host have always shown a definite drop in adult anopheline densities.

Headlee (1942) suggests that the population in stables represents a special concentration of adults. The consistent higher counts that have been found in this type of shelter would indicate that such is the case.

Animal shelters have shown themselves to be, by far, the best and most reliable type of adult station. Either away from or adjacent to the breeding area they provide the best practical index to anopheline densities. As a rule, only when an animal shelter was not available were the other types of adult stations utilized.

Privies: This type of baited station has not been found very satisfactory and is rarely used in the state unless in a shaded location immediately adjacent to a breeding area or an animal lot.

The privy is easy to examine, but because of its usual exposed location and construction, it has not been desirable to use. The sanitary privy now prevalent in the state is provided with cross ventilation at the top and this has lessened greatly its usefulness as an adult station, an old type privy being much more suitable.

In addition to the ventilation drawback, an obvious limitation of the privy is the intermittent presence of the host.

The general superiority of animal shelters over privies has been shown by comparative counts in the two types. One check showed a cow-mule shed having 150 *Anopheles quadrimaculatus* adults while a privy within 30 yards of the shed yielded only 5 specimens. Numerous other observations have shown similar comparative counts although the difference has not always been as great as in the above case.

NONBAITED STATIONS.—The stations which fall in this group usually are most satisfactory when very near to the breeding area. In general, the ecological factors of light, wind, and temperature appear to have more significance in these types than in baited stations.

Culverts—Bridges: These two types are similar in their use as adult stations and can be considered together.

Bridges and culverts are frequently windy and this decreases their suitability since anophelines are less likely to seek shelter there. In addition, under windy conditions the adults are frequently easily disturbed and flighty, making capture difficult.

In regard to adult counts, both types usually are less satisfactory than animal shelters but they do have several advantages over that type: being located near breeding areas, showing male anophelines regularly, and being easier to inspect thoroughly.

Round and box culverts have been employed but the latter type has shown higher counts and is more readily examined.

Wooden, cement, and steel bridges have been employed, all types being about the same in their suitability. Bridges which have recesses at each end between the supports and with a minimum of light are best.

Anopheline House: This term describes a wooden structure 3 by 3 by 6 feet which has been used as an adult station in the midst of or adjacent to a breeding area. Being a nonbaited station, it is not used at distances more than about 500 feet from a breeding area. As the distance from a breeding area increases, the dispersal of the mosquitoes from that area and the number of available baited and non-baited resting places are likewise augmented. Consequently, the chance of mosquitoes resting in this nonbaited station is so greatly diminished that it is of little or no value.

Usually built of scrap lumber, the anopheline house consists of four sides (one containing the entrance opening) and an overlapping top. The structure is fastened together with hooks which, together with the overlapping top, produce a fairly rigid building easily assembled or disassembled. Transported to the desired site in sections, the house can

be erected within 10 minutes. The entrance opening sometimes has a piece of burlap over it, but houses without this device have given as good or better results, so it is not recommended.

Minor modifications of the building have been made in the various parts of the state, but these apparently have no effect on the usefulness of the structure. The principal construction detail to be followed is to make all sections fit evenly when in place so that no crevices remain, since such openings afford resting places which usually are difficult to examine.

The structure offers approximately 75 square feet of resting surface, can be inspected with ease, and is quickly erected or dismantled. Its portability allows it to be used in several localities during a season if this is desired.

The chief factor affecting the usefulness of the house appears to be its location in the field. Open, sunny places are to be avoided; placement should be such that the house is shaded and cool.

During 1944, over 50 anopheline houses were used in the state and results indicate that the structure has a distinct place on a malaria control program. Many times breeding conditions were immediately reflected in the adult captures at adjacent anopheline houses. In several instances breeding was indicated where larval inspection and adult stations (animal shelters) less than a quarter of a mile distant did not show it. For example, at Fayetteville, an animal shelter less than a quarter of a mile from a breeding area showed 3 adult *Anopheles quadrimaculatus* from June 12 to September 9, two of these taken in the period August 7 to 19. An anopheline house in the midst of the pits likewise showed low counts until the two collections of the period August 7 to 19 when 7 males and 10 females were taken. The sudden increase indicated that some breeding had been overlooked during larval inspection since larvicide applications were being made only when large anopheline larvae were found in a water course. A recheck located the source of larvae and after the pits were treated with a larvicide, subsequent adult counts dropped to zero by September 4. Thus, by indicating immediately an oversight in larval inspection, the anopheline house may have prevented subsequent heavy breeding. The animal shelter probably would have shown the same omission in inspection, but only after larval breeding had become much heavier.

In addition to detecting the oversight in larval inspection, the anopheline house localized the breeding area (there were a number of other possible breeding sources within a half-mile radius) thereby reducing the amount of larval inspection time necessary to find the exact location of the breeding.

The largest number of each of the common anophelines that was ever taken in a single collection with these structures was 7 males and 15 females *Anopheles quadrimaculatus*, 90 males, 20 females *A. crucians* and 23 males and 49 females *A. punctipennis*. The larger number of *A. crucians* and *A. punctipennis* does not indicate that these species are attracted more to anopheline houses than is *A. quadrimaculatus*. The high counts of both *A. crucians* and *A. punctipennis* were made in the vicinity of Fort Bragg, North Carolina, where larvicide treatment in 1944 was carried out only where *A. quadrimaculatus* larvae were breeding. As a result, two larval stations were oiled, each a single time, during the 1944 season and this permitted the uncontrolled breeding of the other anophelines.

The anopheline house type of adult station has been used for several purposes in the state:

(1) As a check on larval inspection where the breeding area is difficult to dip thoroughly, *i.e.*, brick pits, rice fields, marshes, and hoof prints.
(2) As a check on water courses which are not being sampled. This aspect saves on sampling time and allows larval inspection to be concentrated where it is most needed.
(3) As a bait station when placed adjacent to animal pens where no suitable shelter is provided.
(4) As an adult station in or adjacent to a breeding area.

In inspecting an anopheline house, one should go over the resting surfaces several times since the movement of the observer in the close quarters may disturb specimens resting on the side back of the inspector. In houses placed over vegetation, it is also advisable to stir up the ground cover so that any anophelines resting

there will fly to a board surface.

The anopheline house is meant to take the place of nail kegs and small boxlike containers which have been recommended for sampling adult populations. It is not to be inferred from this statement that these devices are of no value since other workers have reported success with them (Goodwin 1942). The writer, however, feels that the anopheline house, by its size, provides more uniform and favorable ecological conditions together with a larger area of resting surface for the mosquito thus making it more suitable for measuring anopheline densities than the other devices. Nail kegs and small boxes are less expensive and easier to transport, but these factors appear to the writer to be outweighed by the above points.

LIGHT TRAPS (New Jersey Type).—This type of sampling apparatus has been the subject of much discussion in regard to its value in obtaining *Anopheles quadrimaculatus* densities. Carpenter (1942) states that at Camp Robinson, Ark. "mosquito traps of the New Jersey type compared favorably with hand collection methods for measuring adult densities of *A. quadrimaculatus*." As no animal shelters are included among Carpenter's diurnal resting places, this favorable comparison is understandable.

Huffaker & Back (1943) report that near Fort du Pont, Del., in 1942 an average of 4834 female *Anopheles quadrimaculatus* was estimated per weekly inspection of a barn adjacent to the post whereas a light trap on the post averaged only 105 per week. They state that the use of barns for obtaining *A. quadrimaculatus* densities is far more satisfactory than the use of New Jersey traps. Huffaker & Back conclude very aptly that, where the numbers of malaria mosquitoes are small, *i.e.*, 25 to 200, as is often the case in malarial regions, the New Jersey trap can hardly be expected to catch a sufficient number of *A. quadrimaculatus* to serve as a useful device on a malaria control program.

The writer definitely agrees with this conclusion as to the usefulness of light traps on such work, particularly with reference to the density aspect. When *A. quadrimaculatus* densities are great, any type of nearby resting place or trap will attract a goodly number.

Actually, the question of the use of light traps on a malaria control program is not whether or not the species can be caught by the trap (this has been proved) as is so often argued, but whether this method can give a true and practical picture of the situation in comparison to other types of adult sampling. Such a comparison would include these criteria: (a) relative densities of *quadrimaculatus* taken, (b) the amount of time required to operate each type, (c) expense involved. If an animal shelter versus light trap comparison is made on these points the following observations are forthcoming: (a) animal shelter densities are much higher than those of light traps, (b) an inspector can visit 5 to 10 animal shelters (10 minute catches) in the time it takes to check 3 light traps and look over the catch, (c) animal shelters involve no expense but light traps consume electricity and fan motors frequently have to be rewound which is costly. Naturally the above comparison would vary depending upon the number of units involved and the distance between units. Light traps have one advantage over animal shelters in their general use in urban areas or military posts where animal sheds are not available.

Forty-five light traps have been available for use on the Malaria Control work in North Carolina but, other than for a short period in 1942, these have been mainly at the disposal of military establishments which find them chiefly valuable as indicators of mosquito densities.

HOLLOW TREES.—This type of resting shelter has not been used on a permanent basis but only when seeking to locate a breeding place or to determine the density of larval production. Hollow trees show both males and females readily; such collections in a swamp usually indicate that it contains the source of breeding.

THE DISTRIBUTION OF ADULT STATIONS IN THE CONTROL AREA.—In conducting malaria control programs, drainage, larvicide and other anti-mosquito operations are limited to an orbit within one mile of the area being protected from the disease. This method is based on the fact that the malaria mosquito rarely has a flight range of over a mile. It is obvious that to have effective control it is necessary to keep the number of malaria mosquitoes within, or in the immediate vicinity of, the protected area at a minimum. It is also evident that,

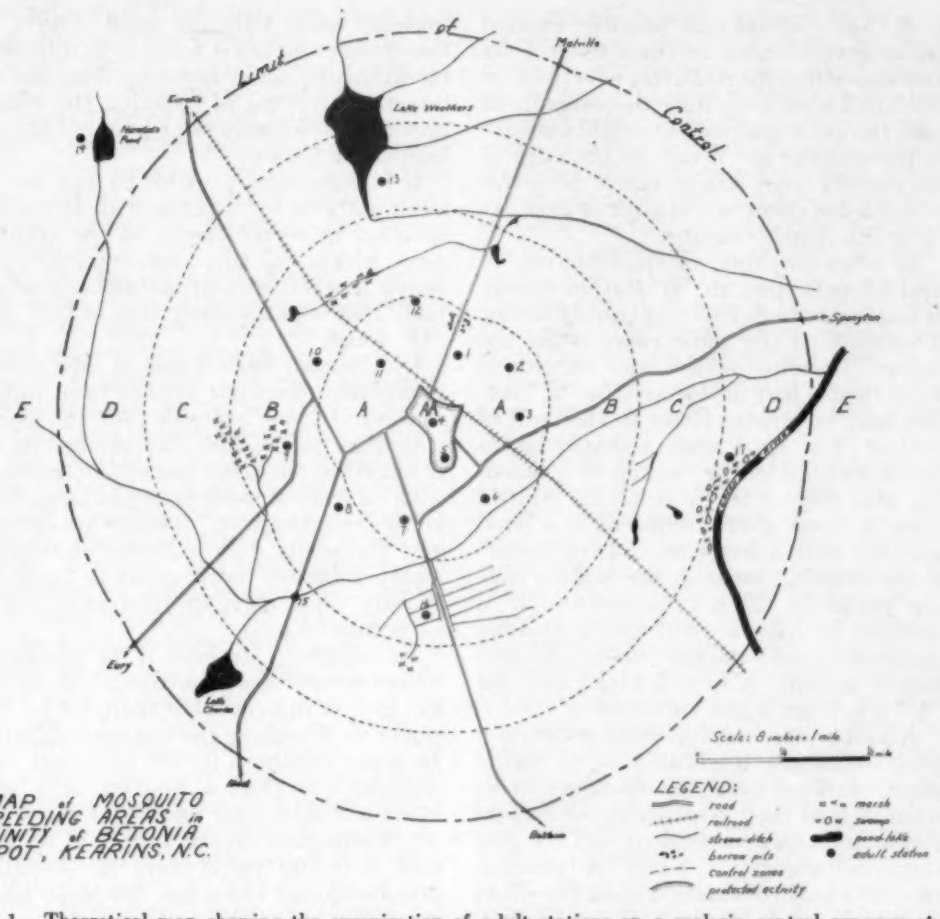

FIG. 1.—Theoretical map showing the organization of adult stations on a malaria control program at Kearins, North Carolina.

as distance from the protected activity increases, the mosquito-density, other factors being equal, theoretically will also be augmented since a greater area not under control is involved within the flight range of the mosquito. To facilitate interpretation of adult data, therefore, the control zone is subdivided into quarter-mile bands, each band being given a letter designation (A, B, C, D, Figure 1) depending on its distance from the protected area. Any part of the protected area is known as "AA" territory; all areas outside the control zone are considered "E" territory.

The general organization of the adult station locations is to surround the protected activity with stations one third to one fourth miles apart in the "A" or "AA" bands (Stations *1, 2, 3, 6, 7, 11, 12*) and to place the B-C-D stations near heavy breeding areas. When a ring of "A" or "AA" stations cannot be maintained because of the lack of suitable shelters in certain localities, "B" stations are used to fill in the gaps (Fig. *1, 8, 9, 10* fill gap between *7* & *11*). The policy is to have approximately half to three-fourths of the adult stations in the "A" and "AA" zones. Within the protected activity, stations are placed near the breeding areas.

One or two stations of the "C" and "D" categories are desirable but not always necessary. The object is to keep the "A" and "AA" zones free or nearly free of malaria mosquitoes and so long as this is done, the counts in "C" and "D" stations, even though high, have little significance. If adults are showing up in "A" stations, then successively higher counts

in B-C-D shelters can possibly explain the source. Stations in these outer belts may also attest the relatively effectiveness of control operations since theoretically at least the adult population should increase as the stations get nearer to the edge of the control zone. Many times, however, topographic changes will alter or even reverse this density picture.

In order to check on the efficiency of control operations, an "E" station usually at least a half-mile from the control limits, is established. In some cases when the nearest breeding area under control is more than a half mile away the "E" station may be erected closer to the limit of control (Fig. 1). A station should be selected which is in the vicinity of a breeding area similar to those of the control zone. A check shelter adjacent to a pond does not give a true comparative picture if the breeding areas in the control zone are primarily ditches. Sometimes it is difficult to find a good check station, particularly in localities where the protected activity is in a lowland and the "E" zones are in the surrounding hills.

Another plan of adult station distribution sometimes advocated is to locate adult stations near the breeding areas regardless of their position in the control zones. Such an arrangement will not give the necessary ring of adult "A" station, places an equal evaluation upon the whole control zone (A–D), and is based on the assumption that all breeding places are known. The latter is usually false since adult stations frequently reveal the location of unknown water courses. Without a ring of "A" stations, there would also be no way of determining that *Anopheles quadrimaculatus* adults were not entering into the protected zone from the "B" and "C" areas through sections in the "A" zone which, lacking water courses, did not contain adult stations.

In the event that an adult station shows high counts and the known water courses in its vicinity are negative, additional temporary adult stations may be erected to aid in discovering the source of breeding. By selecting adult stations of approximately the same sampling suitability, it is possible through comparison of the relative numbers of *Anopheles quadrimaculatus* taken in each temporary station surrounding the high station to determine the direction of the unknown breeding area. Utilizing adult counts in this manner makes it possible to intensify larval inspection in a certain direction or directions instead of covering the entire area in quarter-mile radii centered on the high adult station.

It is sometimes possible by the use of adult stations to dispense with larval inspection in certain parts of the control zone which do not look conducive to heavy *Anopheles quadrimaculatus* production. This is particularly true of "C" and "D" zones.

On the same basis where an area of war importance does not appear from initial surveys to be suitable for excessive *Anopheles quadrimaculatus* production, it is placed on an adult inspection schedule with no control work or larval inspection being done. Only "A" stations are erected and the adult data collected determine whether further work needs to be done. Weekly, bi-weekly, or tri-weekly collections may be made.

In selecting stations it is advisable, where several are available at a desired locality, to inspect all of them for several weeks to determine the one most suitable. In some instances it will be found that stations less than a quarter of a mile apart will show wide variations in counts. At Wilmington, North Carolina, an animal shed 200 yards from the breeding area contained 150 adult *Anopheles quadrimaculatus*, yet three other suitable animal shelters within a quarter of a mile of the forementioned station and the anopheline source showed an aggregate of four specimens. The high adult station here was located between the breeding areas and the animal shelters having the low counts.

The previously cited example shows the necessity of selecting the best animal shelters and also of maintaining a ring of adult stations around the protected activity. It further illustrates the fact that, in most instances, *Anopheles quadrimaculatus* rarely flies in any great numbers more than one-quarter to one-third of a mile from its breeding place when blood meals are available at those distances. In regions where *A. quadrimaculatus* densities are much higher than those in North Carolina it is probable that this flight range would be augmented.

When one station shows a drastic decrease in adult density it is advisable to

inspect other nearby shelters also. This is to eliminate the possibility that the decrease is due to a change in shelter preference rather than control efforts.

INSPECTION OF ADULT STATIONS.—The inspection of an adult station entails careful observation by a competent individual. Observation is aided by a flashlight and the mosquitoes are taken in a chloroform killing tube.

In making the adult density observation, a time limit of ten minutes is placed upon the inspector's activities. By this method the weekly catches at a station are strictly comparable and the chances of excessive time expenditures are reduced. The obvious limitation to this method is that stations having total densities of 500 to 5000 and higher will show approximately the same number of specimens (80, the maximum hand catch possible) taken. However, this limitation can be overcome by estimating the number of adults remaining after the 10 minute collection and then proportioning the species according to the ratio obtained in the hand catches. Boyd (1927) has used the 10 minute catch period, but King (1928) reports it unsatisfactory because in his investigations a number of different locations were being visited at a station and it was not possible under those conditions to obtain a proportionate part of the mosquitoes from the various places in the limited time. King's work was carried out in areas not under control, thus measuring the natural anopheline abundance. Under the work discussed in this article, however, control measures were being practiced and the data desired from adult stations were different. In other words, if an adult station in the "A" or "AA" zone showed 10 or more malaria mosquitoes, control was not considered satisfactory and steps were taken to bring about a reduction in the population. The objective of the program being to keep *Anopheles quadrimaculatus* in the "A" and "AA" zones below 10 per station it made little difference what the total density of malaria mosquitoes in each "A" or "AA" station was since, for practical purposes, control was unsatisfactory whether the count was 12, 50, or 300. Therefore, a weekly 10-minute catch served as a more practical index to anopheline breeding than would a total density collection. With the latter method in a large barn where 40 specimens had been captured in 10 minutes one week, the inspector finding specimens scarcer the next week might double or treble his time and in the end obtain approximately the same number of specimens as during the previous week. In such case, the effect of control measures would not be apparent in the counts even though an actual density reduction had occurred. To counteract this inaccuracy, it would be possible to place collections on a density-time basis, but on a large scale malaria control program, where many of the inspectors are not entomologists and time is limited, such calculations are not practical nor compatible with the aim of the program.

Although the 10-minute catch period is the standard observation time, an inspector should spend more time in his first visit to a station in order to find the principal resting areas. Frequently one end or corner of a stable will contain the majority of specimens and inspection should be concentrated there. In other instances, the adults may be under a lean-to or in a harness shed adjacent to the stable rather than in the stable itself. Usually, however, the anophelines are within the animal shelter, but the occasional anomalies in their behavior call for a thorough initial search of the adult station. This wide variation in behavior is a point in favor of using small animal shelters where the number of possible obscure resting places is reduced.

A routine inspection schedule is necessary in order to obtain the most accurate results. All stations should be inspected in so far as possible on the same day of each week for two purposes; to provide a uniform time interval between catches and to remove the possibility that variations in ecological conditions on the night prior to the observation might be responsible for differences in the density records.

In certain instances it has been desirable to make adult *Anophels quadrimaculatus* counts on successive days to determine the extent of the breeding. The data derived from such observations show that when breeding is moderate, adult counts will remain approximately the same each day. At Elizabeth City, North Carolina, total daily density counts from Tuesday through Friday of one September week ran 39, 38, 34, and 14. On Thursday of the two previous weeks the

count was 41 and 40 while for the two succeeding weeks the number was 26 and 30. These data substantiate the point that the adult population in a station is not static (Boyd 1930). If little or no daily turnover occurred, not only would successive daily counts be lower but the single daily totals for either the preceding or succeeding week would be much higher than the last three successive daily counts. The fourth consecutive daily count showed a definite decrease which may have been due to a depletion of the adult reservoir in the nearby swamp or to adverse flight conditions.

On the other hand higher counts were sometimes made on the first day of successive daily inspections. In these instances total densities were low (10 to 12) and succeeding counts dropped to 3 or 4. Such variations indicate light, erratic, breeding or distant heavy breeding with a small reservoir of adults to refill the station.

INTERPRETATION OF ADULT COUNTS.—The week-by-week adult captures at a station give an indication of the effectiveness of control in the vicinity of that particular station. The data from each station, in general, should be compared only with other data from that station and not in relation to the counts in other stations unless they are of the same type and equivalent in suitability.

As heretofore mentioned, the object of the malaria control operations has been to keep malaria mosquitoes from getting into the protected activity in any appreciable numbers. Consequently, it is desirable that counts in "A" and "AA" stations remain low (below 10) and, so long as this is accomplished, it is immaterial what the *Anopheles quadrimaculatus* densites are elsewhere in the control zone. There is a tendency among supervisors of operations to concern themselves when "B-C-D" stations show high counts even though the "A" stations in the line of flight to the protected activity are low or negative. This tendency is not compatible with an understanding of the object of the program and frequently causes unnecessary expenditure of labor and material. The writer is of the opinion that in many cases control is not required in the outer half mile of the control zones since the mosquitoes breeding there rarely fly into the "A" or "AA" zones. This may not always be true since a heavy breeding area a half to three quarters of a mile distant from the protected area without intervening animal or topographic barriers between it and the "A" and "AA" areas can cause high counts in the "A" territory. It would seem advisable in most control programs to begin operations in "A" and "AA" zones and work outward until the adult counts in "A" and "AA" were reduced to a safe level. Such a procedure is both feasible and economical and should replace the general plan to cover a one-mile control zone at the onset of operations. However, in this gradual, expanding procedure of control operations, exceptions should be made in cases where it is definitely known that large, heavy breeding areas are present in the "B" or "C" zones. Such heavy breeding areas should be cared for first, along with the "A" and "AA" zones.

A station having consistent high counts indicates either ineffective control or unknown breeding areas or both. Effective control of the source usually is reflected in adult collections 2 weeks after treatment with larvicide. In some cases a reservoir of adults in nearby swamps may extend this period.

Sudden increases in density at a shelter, including many male mosquitoes, denotes that the breeding is in the immediate vicinity of the station. The cause for such flare-ups is usually easy to discover and remedy.

A reduction in the count at a high station to a low level should not be considered indicative of effective control until it extends over a period of 2 or more weeks. Stations which have dropped as low as zero and 1 in one week have jumped to densities of 45 and 61 the following week. Such increased counts are probably due to the emergence of a new generation of adults. In some areas low and high weekly counts have alternated over a period of 6 weeks indicating the emergence of definite generations every 10 to 12 days.

Adult counts reflect breeding that has been occurring the previous 10 to 14 days and in certain cases the failure to locate the source is due to the temporary nature of the water course in which the breeding occurred.

The entomological data secured from the adult counts of one season can be utilized in outlining and conducting control

and inspection operations for a following year. It should be kept in mind, however, that the ecological conditions present one year will not be the same the next year and likewise the adult counts in various stations may also be vastly different. At New Bern, North Carolina, the adult records for 1943 showed five stations with the highest *Anopheles quadrimaculatus* counts. In May of 1944 full inspection facilities were not available, so adult checks were limited these high stations of 1943. In a total of 22 inspections the stations yielded 29 adults, the highest single collection being seven specimens. At the time of the last inspection all of the adult stations in the area were checked, the results showing one "A" shelter with a total of 33 *A. quadrimaculatus*, a station in which out of 20 inspections the previous season, only 16 specimens had been taken. A tidal marsh in which there had been little or no breeding in 1943 was now found to be producing heavily.

In interpreting the adult counts in an area, the type of station involved should be considered in relation to the density obtained. An anopheline house in the "A" zone having a count of five males and four females is of more concern than a stable the same distance from the protected activity which has a density of 15 females. Primarily the anopheline house is sampling the *Anopheles quadrimaculatus* on the wing while the stable count represents a concentration of adults. Thus it can be assumed that if a stable could be substituted at the location of the anopheline house it would show a far greater count than the non-baited station. In addition, the breeding source for the anopheline house can be said with a fair degree of certainty to be located in the "A" zone within a short distance of the station while the location of the source for the first mentioned stable may be in "A," "B," or "C" zones. From this interpretation it can be seen that the area near to the anopheline house should have the first priority on larvicidal and inspection work.

It has been found that animal sheds, reflecting more accurately the density of the anopheline population, show the highest counts. This can be attributed to the animal bait involved. Therefore, it is readily discernible that lower counts in non-baited shelters may many times be more cause for concern than higher counts in animal sheds. No definite ratio value has been established, it depends mainly upon the individual on the spot interpretation not only of the counts, but of the counts in relation to the prevailing ecological conditions and to the location of the station with reference to the protected activity.—10-30-44.

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IMMINENT MEETINGS

The Central Plant Board Meeting will be held at Purdue University, Lafayette, Indiana, on March 27 and 28, 1945.

The Annual Conference of the North Central States Entomologists will be held at Purdue University, on March 29 and 30 in sequence with the Central Plant Board Meeting.

The Mosquito Collecting Program of the Seventh Service Command for 1942–1943[1]

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It is the purpose of this paper to present results of a two year program of mosquito collecting in the 7th Service Command. States included in the Service Command area are: North Dakota, South Dakota, Nebraska, Iowa, Minnesota, Colorado, Wyoming, Missouri and Kansas.

During the spring, summer and fall months of 1942 and 1943, specimens from 18 military installations in this area were sent to this laboratory for identification. Entomological surveys, made by officers from this laboratory, furnished material from 6 additional stations, bringing to 24 the number of stations from which mosquito records were obtained.

METHODS EMPLOYED.—Collections include specimens obtained by the following methods:

1. *Light trap collections* of adult mosquitoes were made throughout the spring, summer and fall months at 12 stations. Traps employed were the standard New Jersey light traps. These were operated nearly every night throughout the season.

2. *Hand collections* of adult mosquitoes were made at all stations. Specimens were taken from daytime resting places under bridges, in culverts, buildings, and trees. Others were collected at night in buildings and in the open while attempting to feed. A few specimens were taken from winter hibernating places. Aspirators and killing tubes were employed in making these collections.

3. *Larval collections* include specimens from a variety of breeding places.

In order to obtain as much information as possible concerning the abundance and ecological relationship of each species, it was required that two copies of laboratory form 2 7CA be completed for each collection and sent to this laboratory with it. One copy was subsequently returned to the collector with identification of specimens submitted. The essentials in this form are shown herewith.

Collections at each post are made under the supervision of the post surgeon. The post sanitary officer and his assistants operate the light traps, and make hand and larval collections. The New Jersey traps are obtained from the post engineers who, with the advice of the post surgeon, carry out the mosquito control program.

RESULTS OBTAINED.—A total of 4882 collections made during 1942 and 1943, netted 79,572 mosquitoes, representing 43 species. The 1255 collections made in 1942 yielded 20,327 specimens. Collections in 1943 totalled 3627, with 59,245 specimens captured.

The following table indicates the extent to which each type of collecting method was employed during each of the years with which this report is concerned.

Table 1.—Data on 1942 and 1943 Collections.

TYPE OF COLLECTION	NUMBER	SPECIMENS TAKEN
	Collections of 1942	
Trap	888	13,758
Hand	187	2,039
Larval	180	4,530
	Collections of 1943	
Trap	2,405	21,406
Hand	409	5,872
Larval	813	31,967

Although mosquitoes were collected and sent to this laboratory for identification during every month in 1943, the period of greatest activity for both 1942 and 1943 extended from the end of May to the latter part of October.

Following are state lists of species of mosquitoes found in the 7th Service Com-

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Table 2.—State lists of species of mosquitoes found in the Seventh Service Command during the seasons of 1942 and 1943.

Missouri

Anopheles barberi
Anopheles punctipennis
Anopheles quadrimaculatus
Aëdes aegypti
Aëdes atlanticus-tormentor
Aëdes canadensis
Aëdes dorsalis
Aëdes dupreei
Aëdes nigromaculis
Aëdes sollicitans
Aëdes sticticus
Aëdes triseriatus
Aëdes trivittatus
Aëdes vexans
Culex apicalis
Culex erraticus
Culex peccator
Culex pipiens
Culex quinquefasciatus
Culex restuans
Culex salinarius
Culex tarsalis
Mansonia perturbans
Orthopodomyia alba
Orthopodomyia signifera
Psorophora ciliata
Psorophora confinnis
Psorophora cyanescens
Psorophora discolor
Psorophora ferox
Psorophora horrida
Psorophora howardii
Psorophora signipennis
Theobaldia inornata
Uranotaenia sapphirina

Nebraska

Anopheles punctipennis
Anopheles quadrimaculatus
Aëdes canadensis
Aëdes dorsalis
Aëdes flavescens
Aëdes nigromaculis
Aëdes sollicitans
Aëdes sticticus
Aëdes triseriatus
Aëdes trivittatus
Aëdes vexans
Culex apicalis
Culex pipiens
Culex restuans
Culex salinarius
Culex tarsalis
Mansonia perturbans
Orthopodomyia alba
Orthopodomyia signifera
Psorophora ciliata
Psorophora discolor
Psorophora ferox
Psorophora horrida
Psorophora signipennis
Theobaldia inornata
Uranotaenia sapphirina

South Dakota

Aëdes nigromaculis
Aëdes vexans
Culex tarsalis
Psorophora signipennis

Wyoming

Aëdes dorsalis
Aëdes nigromaculis
Aëdes stimulans
Aëdes trivittatus
Aëdes vexans
Culex tarsalis
Theobaldia inornata

Iowa

Anopheles punctipennis
Anopheles walkeri
Aëdes canadensis
Aëdes fitchii
Aëdes stimulans
Aëdes sticticus
Aëdes triseriatus
Aëdes trivittatus
Aëdes vexans
Culex apicalis
Culex pipiens
Culex restuans
Culex salinarius
Culex tarsalis
Mansonia perturbans
Psorophora horrida
Theobaldia inornata
Uranotaenia sapphirina

Kansas

Anopheles punctipennis
Anopheles quadrimaculatus
Aëdes dorsalis
Aëdes flavescens
Aëdes nigromaculis
Aëdes sticticus
Aëdes triseriatus
Aëdes trivittatus
Aëdes vexans
Culex apicalis
Culex erraticus
Culex peccator
Culex pipiens
Culex quinquefasciatus
Culex restuans
Culex salinarius
Culex tarsalis
Mansonia perturbans
Orthopodomyia alba
Orthopodomyia signifera
Psorophora ciliata
Psorophora confinnis
Psorophora cyanescens
Psorophora discolor
Psorophora ferox
Psorophora horrida
Psorophora howardii
Psorophora signipennis
Theobaldia inornata
Uranotaenia sapphirina

Minnesota

Anopheles occidentalis
Anopheles punctipennis
Anopheles walkeri
Aëdes canadensis
Aëdes cinereus
Aëdes dorsalis
Aëdes fitchii
Aëdes nigromaculis
Aëdes spenceri
Aëdes sticticus
Aëdes triseriatus
Aëdes trivittatus
Aëdes vexans
Culex apicalis
Culex restuans
Culex tarsalis
Mansonia perturbans
Theobaldia inornata
Uranotaenia sapphirina

Colorado

Aëdes dorsalis
Aëdes nigromaculis
Aëdes stimulans
Aëdes trivittatus
Aëdes vexans
Culex tarsalis
Theobaldia inornata

mand during 1942 and 1943. New state distribution records were recorded for 15 species. No specimens were received from North Dakota. A list of new state records has been prepared for separate publication (Olson & Keegan 1944).

LARVAL ECOLOGY.—Collections of larvae were taken from a variety of sources, which for convenience have been classified as follows:

Semi-permanent and permanent ponds
Swamps
Temporary pools
Woodland pools
Foul stagnant pools
Lake shores
Streams
Springs
Artificial receptacles
Tree holes
Potholes
Sink holes
River beds

Several species displayed great variation in habitat. *Anopheles punctipennis* in particular was collected from every type of habitat except tree holes. Five larvae of this species were taken from foul, stagnant pools contaminated with sewage. Of special interest also was *Aedes triseriatus*, ordinarily found only in tree holes, but here recorded from permanent ponds, swamps, woodland pools, artificial receptacles and potholes, in addition to tree holes.

Few species were restricted to a particular type of habitat. Semipermanent and permanent ponds, with 22 species recorded, and temporary pools, also with 22 species, led the list of habitats in number of resident species. Swamps, with 17 species, and artificial receptacles with 17, were other favorite breeding places.

Perhaps the most clear-cut habitat group occurred in tree holes, and consisted of *Anopheles barberi*, *Aëdes triseriatus*, *Orthopodomyia alba* and *Orthopodomyia signifera*. Alhtough *Culex restuans* and *Psorophora confinnis* were taken from tree holes, their presence in so many other types of breeding places clearly indicates that they are not true members ot his group.

Collections taken from a foul stagnant pool contaminated with sewage yielded: *Anopheles punctipennis*, *Aëdes dorsalis*, *A. vexans*, *Culex pipiens*, *C. restuans*, *C. salinarius*, *C. tarsalis*, and *Theobaldia inornata*. Each of these species, except *C. salinarius* has been recorded from such a habitat previously.

Among 14 species taken from potholes are *Anopheles punctipennis*, *A. quadrimaculatus*, *Culex apiculis*, *Aëdes triseriatus*, and *Psorophora ciliata*. With the exception of the latter two species, more larvae of these mosquitoes were taken from this habitat than from any other.

In addition to larvae obtained from habitats previously considered, numerous specimens of *Aëdes sticticus* and *A. vexans* were received from Fort Leavenworth, Kansas, where they had been reared from eggs contained in soil and wood pulp samples collected at that station.

Eggs of *Aëdes sticticus* were found in 34 samples taken from February to August 1943, with a total of 885 specimens reared. Collections of eggs of *A. vexans*, 20 in number, were made during February, March and April, 1943, and a total of 781 specimens was obtained.

COLLECTIONS OF ANOPHELINE MOSQUITOES.—Anopheline mosquitoes were taken in Missouri, Nebraska, Kansas, Iowa and Minnesota. Although no anophelines were collected in the remaining states in the Service Command area, it is believed that more extensive collecting will reveal their presence, as several workers have taken them in all of the states concerned except Wyoming.

Five species of the genus Anopheles were collected. These are: *A. barberi*, *A. walkeri*, *A. occidentalis*, *A punctipennis*, and *A. quadrimaculatus*.

Anopheline mosquitoes comprised 12.73 per cent of the total mosquito catch in 1942, and 11.54 per cent in 1943. Actual numbers of anophelines collected were 2587 in 1942, and 6835 in 1943. As the 1943 collections were roughly three times as large as in 1942, it is interesting to note that the percentage of anophelines remained relatively the same.

Anopheles punctipennis and *A. quadri-*

Table 3.—Summary of collections of anopheline mosquitoes in 1942 and 1943.

Species	Number Collected	Per Cent of Collection
Analysis of Anopheline Catch for 1942		
Larvae:		
A. barberi	6	0.87
A. punctipennis	623	90.29
A. quadrimaculatus	15	2.17
A. pupae	46	6.67
Adults—Hand Collections		
A. punctipennis	23	3.64
A. quadrimaculatus	609	96.36
Adults—Trap Collections		
A. barberi	2	0.16
A. punctipennis	127	10.04
A. quadrimaculatus	1136	89.80
Total Anopheles Collected in 1942		
A. barberi	8	0.31
A. punctipennis	773	29.87
A. quadrimaculatus	1760	68.04
A. pupae	46	1.78
Analysis of Anopheline Catch for 1943		
Larvae:		
A. barberi	6	0.17
A. punctipennis	5005	95.99
A. quadrimaculatus	29	0.56
A. species pupae	172	3.30
A. species larvae	2	0.04
Adults—Hand Collections:		
A. occidentalis	15	1.40
A. punctipennis	666	62.19
A. quadrimaculatus	366	34.17
A. walkeri	1	0.09
A. species	23	2.15
Adults—Trap Collections:		
A. barberi	6	1.09
A. punctipennis	208	37.82
A. quadrimaculatus	318	57.82
A. walkeri	18	3.27
Total Anopheles Collected in 1943		
A. barberi	12	0.17
A. occidentalis	15	0.22
A. punctipennis	5879	86.01
A. quadrimaculatus	713	10.43
A. walkeri	19	0.28
A. species	25	0.37
A. species pupae	172	2.52

maculatus were the most numerous species of the genus. Although *A. quadrimaculatus* was more commonly taken in trap collections than other forms, very few larvae of this species were collected. In both 1942 and 1943, *A. punctipennis* composed over 90 per cent of the larval catch of anophelines. The following data gives an analysis of the anopheline catches in both years. Specimens too small (early instars) or too badly damaged for specific identification are listed as *Anopheles* species.

DATA ON SPECIES OF ANOPHELINES COLLECTED.—

1. *Anopheles quadrimaculatus*

A. Distribution Records:

This species was most numerous in Missouri and Kansas collections, although specimens were taken in Nebraska. Posts from which this species is recorded are: Jefferson Barracks, Mo.; Camp Crowder, Mo.; Camp Babler, Mo.; Fort Leonard Wood, Mo.; Fort Riley, Kan; Fort Leavenworth, Kan.; Winter General Hospital, Topeka, Kan; Fort Omaha, Neb.; Nebraska Ordnance Plant, Mead, Neb.

The greatest number of specimens taken from one post was 678 collected at Fort Leonard Wood, Mo., in 1942. This record is closely followed by one of 605 specimens from Jefferson Barracks, Mo., also in 1942. Fort Leavenworth, Kan., yielded 348 specimens in 1942 and 418 in 1943. 120 specimens were collected at Fort Omaha, Neb., in 1942; however, only 8 were taken at this post during the 1943 season.

B. Seasonal Incidence:

Fort Leonard Wood, Mo. June 21 to Oct. 4.

Fort Leavenworth, Kan. July 6 to Nov. 4.

Jefferson Barracks, Mo. July 9 to Sept. 30.

C. Larval Habitats: ponds, swamps, temporary pools, streams, springs, potholes.

D. Larval Associations: *Anopheles punctipennis, Culex apicalis, C. restuans, C. erraticus, C. pipiens, C. tarsalis, C. quinquefasciatus, Psorophora confinnis, Theobaldia inornata.*

2. *Anopheles punctipennis*

A. Distribution Records:

Although the greatest number of this species was collected in Missouri and Kansas, specimens were also received from Nebraska, Iowa and Minnesota. This was the most numerous anopheline mosquito collected. It was taken at the following posts: Fort Leonard Wood, Mo.; Jefferson Barracks, Mo.; Camp Clark, Mo.; Weingarten, Mo.; Malden, Mo.; Camp Crowder, Mo.; Camp Babler, Mo.; Fort Riley, Kan; Fort Leavenworth, Kan.; Winter General Hospital, Topeka, Kan.; Schick General Hospital, Clinton, Iowa; Camp Ripley, Minn.; Fort Crook, Neb.; Fort Omaha, Neb.; Nebraska Ordnance Plant, Mead, Neb.

B. Seasonal Incidence:

Fort Leonard Wood, Mo. Hand collections of females at intervals from Jan. 10 to March 12; others from May 7 to Oct. 18.

Fort Leavenworth, Kan. June 21 to Nov. 4.

Jefferson Barracks, Mo. June 24 to Oct. 2.

At all stations most occurred in July, August and September.

C. Larval Habitats: Very wide variation. Was taken in all habitats except tree holes.

D. Larval Associations: Was associated with a total of 17 species, mainly with *Culex apicalis, C. restuans, C. salinarius, C. pipiens, Psorophora confinnis, Aëdes texans, Anopheles quadrimaculatus.*

3. *Anopheles walkeri*

Was collected in only two localities—Fort Snelling, Minn. (18 specimens) and Schick General Hospital, Clinton, Iowa (1 specimen). Only adult specimens were collected.

4. *Anopheles barberi*

A. Distribution Records:

Taken only at Fort Leonard Wood, Mo.—6 larvae and 2 adults in 1942 and 6 larvae and 6 adults in 1943.

B. Larval Habitats: 6 larvae taken in artificial receptacles, 6 in tree holes.

C. Larval Associations: *Aëdes triseriatus, Culex restuans, Orthopodomyia signifera, O. alba.*

5. *Anopheles occidentalis*

This species is represented in the 7th Service Command Laboratory collections by 15 specimens taken by hand at Camp Ripley, Minn. (Additional species of *Anopheles* collected during 1944 are *A. crucians* and *A. pseudopunctipennis* from Missouri, and *A. freeborni* from Colorado.)

COLLECTIONS OF CULICINE MOSQUITOES.—Over the two-year collecting period the most abundant species found were *Culex restuans* and *Aedes vexans.* Both were found in a variety of larval habitats and were abundant throughout the season. Other culicine mosquitoes that were taken in large numbers are *C. tarsalis, C. salinarius, C. apicalis, Aedes nigromaculis, Psorophora confinnis* and *Theobaldia inornata.* The last-named species displayed an interesting seasonal distribution, in that it was taken mainly in the spring and the fall. No specimens were taken between July 1 and September 4, and the majority were not found later in the spring than May 1.

DISCUSSION.—Necessity for carrying out hand, trap and larval collections is evidenced by figures obtained for many species, some of which were found almost entirely in only one type of collection. A case in point is that of *Anopheles quadrimaculatus.* Only 44 larvae of this mosquito were taken, although it was the predominating anopheline species in trap and hand collections.

Although anopheline mosquitoes have been reported in every state in the Service Command except Wyoming, our present knowledge of the distribution of these species throughout the Service Command is inadequate, particularly for the states of North and South Dakota, Colorado and Wyoming. It is anticipated that an enlarged collecting program planned for 1944 will yield additional information on anopheline distribution in these states.

It is interesting to note that malaria cases were reported from military installations in all of the states in the Service Command except North Dakota, and that anopheline mosquitoes were reported from 16 of the 24 stations from which specimens were received. There are civilian records of anopheline mosquitoes in 8 additional vicinities in which military installations are located. A majority of the malaria cases reported were prisoners of war at internment camps throughout the Service Command. Others were soldiers returned from overseas duty who had suffered relapses since arrival in this country. Most infections reported were with *Plasmodium vivax,* although *P. malariae* and *P. falciparum* occurred in lesser numbers.

As it is possible that entrance of only one additional gametocyte carrier in a community may bring about a measurable increase in the incidence of malaria in that community, it seems especially desirable at this time to obtain accurate information as to the distribution and habits of anopheline mosquitoes in this Service Command. Information gathered in an extensive collecting program may prove useful in advising as to the set-up of a control program, both as to scope and measures to employ.

It is significant that *Aëdes aegypti,* vector of yellow fever and dengue, *Culex pipiens* and *C. quinquefasciatus,* vectors of filariasis, and *C. tarsalis,* potential vector of equine encephalomyelitis, are present in the Service Command. Return of cases of filariasis to this country (some cases of infection with filariae are now hospitalized in this Service Command) may make control of culicine mosquitoes of considerable importance in the near future.

SUMMARY.—1. This paper reports results of the mosquito collecting program of the 7th Service Command during 1942–1943. States included are: North Dakota, South Dakota, Nebraska, Iowa, Minnesota, Colorado, Wyoming, Missouri and Kansas.

2. Collections include specimens obtained in hand and trap collections of adults and larval collections. A description of collecting methods and collection data submitted with specimens is given.

3. Collections numbering 4882, made during 1942 and 1943 netted 79,572 mosquitoes, representing 43 species. State lists of species collected are given. An analysis of types of collections is made, and some features of larval ecology are discussed and presented in table form. Five species of the genus *Anopheles* were collected: These are *A. barberi, A. walkeri, A. occidentalis, A. punctipennis,* and *A. quadrimaculatus. A. punctipennis* and *A.*

quadrimaculatus were the most numerous species of the genus. *A. punctipennis* predominated in larval collections and *A. quadrimaculatus* in hand and trap collections. *A. quadrimaculatus* was taken in Missouri, Kansas and Nebraska. The greatest number of individuals of this species taken at one post was 678 specimens collected at Fort Leonard Wood, Mo., in 1942. *A. punctipennis*, the most numerous anopheline, was taken in Missouri, Kansas, Nebraska, Iowa and Minnesota. The most abundant species taken in both years were *Culex restuans* and *Aëdes vexans*.

4. It was found that use of all types of collecting methods was necessary if a true picture of the distribution of a species was to be obtained.

5. Malaria cases were reported in all of the states of the Service Command except North Dakota. Anopheline mosquitoes were reported from 16 of the posts from which specimens were received. Civilian records indicate the presence of anopheline mosquitoes in 8 additional vicinities in which military installations have been established. Most infections reported were with *Plasmodium vivax*. *P. malariae* and *P. falciparum* were present in smaller numbers. Several potential culicine vectors of disease are present in the Service Command. These include *Aëdes aegypti*, *Culex pipiens*, *C. quinquefasciatus* and *C. tarsalis*. Return of cases of filariasis to this country may make control of culicine mosquitoes of more importance in the near future.—9-22-44.

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Effects of Paralytic Insecticides on Heart Pulsations and Blood Circulation in the American Cockroach as Determined with a Fluorescein Indicator[1]

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One purpose of this paper is to introduce to entomology a fluorescent indicator that should be useful in studies of insect physiology, toxicology and behavior. As one example of its application, a description is presented of its use for determining the rate of circulation of the blood[3] in the American cockroach. Having learned how to determine rate of circulation, the writer was able to use the method to study the effects of paralytic insecticides on circulation in paralyzed roaches and, in conjunction with concurrent observations on rate of heart beat, to throw new light on the comparative action of these insecticides.

EXPERIMENTAL APPROACH.—The determination of rate of blood circulation in an insect by the use of an indicator soluble in the blood depends on a definite course of blood flow, the injection of the indicator at a definite point into the blood stream, and the subsequent sharp detection of the indicator at some other point in the body to which it was carried in the blood stream. The reciprocal of the time elapsing from the moment of injection to the appearance of the indicator at the chosen spot is a measure of rate of circulation, suitable for comparative purposes. It was found that the foregoing conditions were fulfilled by injecting an aqueous solution of a fluorescent substance (*e.g.*, fluorescein) into one of the cerci so that the indicator would enter the posterior opening in the dorsal vessel, and after being pumped forward to the head, could be detected visually in successive unsclerotized areas in the ventral part of the body and appendages as it moved back to the point of injection. The presence of the indicator is made visible under the soft, translucent areas of the cuticle by its fluorescence under ultra-violet light. Figure 1, a photograph of an injected female roach, shows as white areas the fluorescence produced and visible under ultra-

[1] Details of this investigation may be found in the author's Ph.D. dissertation deposited in the library of the Ohio State University.

[2] The author, gratefully acknowledges the continued advice and guidance given by Dr. F. L. Campbell throughout the course of this work.

[3] It was not known until this work was completed that similar investigations with fluorescein were being made in the field of clinical medicine by Lange & Boyd (1942).

violet light. Note in particular the five white spots of fluorescence occurring on the tarsus of each leg. These are the pulvilli.

MATERIALS AND METHODS.—The insecticides used are listed in table 1. The ultra-violet light was produced by a *GE-H4* mercury lamp giving radiations of approximately 3600 Ångstroms. The indicator solution carried the trade name *Ultra-violet Fountain Water Green* of the Stroblite Company of New York. The solution was orange and the fluorescence green.

Only one determination of rate of circulation could be made on a single insect, normal or paralyzed. Therefore a group of similar insects of the same sex were used to determine change of rate of circulation during the period of paralysis from a given insecticide. These insects were paralyzed by pipetting not more than 0.02 cc. of a liquid insecticide upon the bases of the legs, by dusting them with a diluted pyrethrum powder, or by exposing them to an atmosphere containing HCN. At intervals from the beginning of paralysis of the group a paralyzed insect was taken from the group, the left cercus was clipped and 0.005 cc. of the indicator solution was injected into it. Then observations were made until fluorescence appeared in the pulvilli in a fore-leg. If fluorescence did not appear within a reasonable time while the heart was beating, other observations were made to try to explain the failure of circulation.

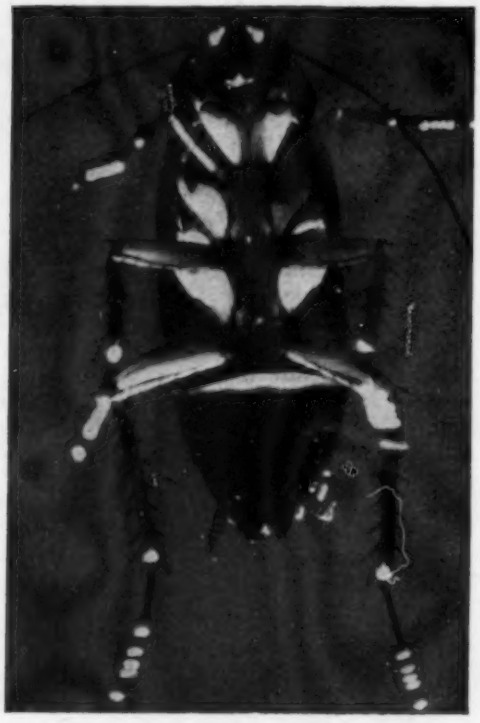

FIG. 1.—Adult American roach injected with fluorescent indicator and photographed under ultra-violet light. All white areas show the lightly sclerotised parts of the body through which fluorescence is visible. Note also the cut cercus, through which the fluorescent indicator was injected.

No attempt was made to measure the absolute rate of hemolymph flow in these tests. Tauber & Snipes (1936) obtained a figure of 34.3 ± 14.4 mm. per minute as the rate in young adult roaches. These authors also found no relationship between variations in velocity and heart rate. Unauthentic calculations on the basis of observations in this work indicate a slower rate of circulation between posterior heart and the appearance of fluorescence in the fore-tarsus.

Other comparable insects, paralyzed as described above, but not injected were used to determine change in rate of heart beat during paralysis. For this purpose it was unnecessary to use a different insect for each observation. With a given insect the normal pulsations were counted by observing the heart directly through the dorsal integument, using a binocular microscope with a strong beam of white light focused at the point of observation. After this insect was paralyzed, counts were made on it in the same way at hourly intervals as long as the heart continued to beat or until the rate of beat had returned to normal.

RESULTS.—A qualitative summary of results is given in table 1. As examples of quantitative results, table 2 shows change in rate of heart beat during HCN paralysis and table 3 shows change in time of blood circulation during paralysis with the same insecticide. Particulars of all experiments are briefly described and discussed below.

All applications of 0.02 cc. of liquid insecticide had a greater or more rapid effect on the nymphs than on the adults, owing no doubt to the greater size and weight of the latter. Similarly the males, being smaller, were usually more susceptible than the females.

Pyrethrum. Whether in liquid or powder

Table 1.—Relative effects of paralytic insecticides on the American cockroach (adults and large nymphs of both sexes).

INSECTICIDES	ULTIMATE EFFECT OF CHOSEN DOSES	EFFECT DURING PARALYSIS ON RATE OF— Heart Beat	Circulation of Blood
Pyrethrum			
1941—O.T.I.	Death	Continuous decline	Stops before heart
Powder	Recovery	Above normal to normal	Little effect
Nicotine			
75 and 1%[1]	Death	Irregular decline	Quickly interrupted
β,β′-Butoxythio-cyanodiethylether			
(*Lethane 384*, 3%)[1]	Death	Sharp drop, rise and fall	Stops soon, irregular
(*Lethane 384*, 1.25%)[1]	Recovery	Sharp drop, rise above normal	Sharp drop, rise
Hydrocyanic acid gas	Recovery	Sharp drop, rise above normal	Sharp drop, rise

[1] Per cent by volume in oil (*Deo-Base*)

form pyrethrum produced rapid and characteristic reactions; increased activity, convulsions, loss of muscular coordination, and finally locomotor paralysis wherein muscular action was reduced to occasional slow appendage movement.

During paralysis of roaches destined to die, pyrethrum caused a continuous decline in rate of heart beat. In those destined to recover the rate of heart beat increased above normal soon after treatment, followed by return to normal as the insect recovered the use of its legs. The rate of blood circulation was fairly well correlated with rate of heart beat, both in lethal and sublethal treatments, but blood circulation ceased before the heart had stopped beating.

Hartzell (1934) and others have shown that pyrethrins attack nervous tissue, producing lesions in the ganglia. In the oriental cockroach, Alexandrowicz (1926) found non-ganglionic lateral nerves lying along the dorsal vessel and nerves running from the ventral ganglia to the heart. If these nerves control heart pulsations and if pyrethrins primarily destroy nervous tissue, one would expect the heart to stop beating as soon as the legs become paralyzed. Actually the heart continues to beat at a declining rate long after the legs are paralyzed in roaches destined to die and is not much affected in those destined to recover. Therefore, either pyrthrins do not quickly reach nerves controlling the heart pulsations or these pulsations are not entirely dependent on the nervous system. The latter seems more probable, because the isolated heart separated from the central nervous system and immersed in physiological saline solution will beat for many hours. The retardation and final cessation of heart beat in pyrethrum poisoning may be caused by secondary effects that are still obscure.

Nicotine. Treatment with 75 per cent and 1 per cent nicotine caused more nearly complete paralysis of the appendages than did pyrethrum and resulted in the death of the insects. Rate of heart beat declined irregularly during period of paralysis of 24 to 48 hours.

Injections of fluorescent indicator were made after treatment with both nicotine concentrations, but all attempts to measure the rate of blood circulation failed.

Table 2.—Average rate of heart pulsations (beats per minute) in American roaches during paralysis resulting from exposure to HCN.

STAGE	NORMAL RATE	PARALYSIS PERIOD IN HOURS 1	2	3	4	5	6	7	8	9	10	11	12
Adult Male	99	11	27	28	46	54	82	96	103	107	106	116	115
Adult Female	99	35	32	37	53	61	89	97	97	103	109	103	107
Nymph Male	94	23	44	55	51	61	67	84	89	95	92	89	99
Nymph Female	100	22	25	31	47	58	82	97	106	98	99	103	110

The normal physiology of blood circulation had apparently been greatly altered, because the fluorescent indicator did not appear in the pulvilli. The following observations on paralyzed roaches tend to explain this disturbance.

Reversal of heart beat was found to occur occasionally in many individuals and would be expected to change the course of blood circulation. Clumps of cells were seen within the heart of various individuals and were thought to act as a dam or obstruction to the forward flow of blood in the heart. The amplitude of heart beat was reduced by nicotine, probably resulting in a less forceful flow of blood and a decreased volume of flow per heart beat. Very little muscular activity, which might be conducive to circulation, was observed in paralyzed roaches. As the tibio-tarsal joint was bent at a sharp angle, it was thought that the normal blood channel to the tarsus might have been constricted, thereby preventing blood flow into the pulvilli and eliminating the chosen endpoint of circulation. Nicotine caused paralyzed roaches to swallow air, resulting in inflation of the crop and further restriction of normal channels of circulation.

Table 3.—Average time of blood circulation (minutes) in American roaches during paralysis resulting from exposure to HCN.

Stage	Normal Time	Paralysis Period in Hours 1	2	4	8	12
Adult Male	6	304	120	80	50	29
Adult Female	3	183	102	14	31	8
Nymph Male	5	230	113	24	8	20
Nymph Female	5	157	148	96	7	5

Although concentrations of nicotine lower than 1 per cent were used to get sublethal effects, none was found that would always induce paralysis followed by recovery. Therefore, sub-lethal effects could not be studied.

Lethane 384. Although the superficial effects of *Lethane* were much the same as those of pyrethrum and nicotine, its effect on heart pulsations was different. In both lethal and sublethal treatments there was a sharp drop in rate followed by a rise and leveling off, lasting for several hours in roaches that finally died. In roaches that recovered the rise was above normal and the rate quickly fell to normal levels. Recovery from *Lethane* paralysis was more rapid than that from pyrethrum.

Only a fragmentary picture of the effect of *Lethane* on blood circulation could be obtained after lethal treatments. The rate was greatly reduced and circulation stopped between 4 and 6 hours after paralysis. The effect of sublethal treatments was determined without difficulty. Generally the normal rate was greatly reduced in 5 minutes after paralysis and increased up to time of recovery. Blood circulation approached normal after 1 hour's paralysis. These results were well correlated with those on heart pulsations.

Thiocyanates are believed by Yeager *et al.* (1935) to cause a decrease or cessation of heart beat and an increase in dilation of the heart by increasing the myotonus of the alary muscles. However, present results compared with those obtained with HCN suggest an additional type of reaction.

Hydrocyanic acid. Observations on rate of heart beat one hour after paralysis showed a great decrease to about one-third normal value (Table 2). Nymphs and adults both showed about the same rates throughout the experiment, and all recovered from treatment. Heart beat rate increased quite rapidly after one hour and rose above the normal rate between 8 and 9 hours paralysis. The rate remained above normal until after 12 hours, and then decreased to normal between 12 and 24 hours as the roaches recovered. The change in rate of blood circulation was well correlated with that of heart beat (Table 3).

It is generally recognized that hydrocyanic acid gas does not produce its effects on nervous tissue, but on the processes of respiration (*e.g.*, Brinley, 1928). Heart beat and circulation are quickly and profoundly affected by restriction of tissue respiration. Steady, slow recovery ensues as this effect wears off. As a similar qualitative effect is shown by *Lethane* and as this compound is related chemically to HCN, it seems not unlikely that *Lethane* may act as a respiratory poison, in conjunction with its effect on increasing the myotonus of the alary muscles.

The relative toxicity of the three contact insecticides was in the following descending order: pyrethrins (most toxic), nicotine, and β,β'-butoxythiocyanodiethyl-ether.

CONCLUSIONS.—Injection of a fluorescent indicator makes possible determina-

tion of rate of blood circulation in normal American roaches and in those paralyzed by certain insecticides. Such indicators should be useful tools in other kinds of entomological research.

Studies of rate of heart beat and of blood circulation in normal and paralyzed American roaches show that the nerve poisons, pyrethrum and nicotine, permit the heart to beat long after the appendages are paralyzed, indicating that nervous control of heart pulsations is secondary to myogenic action. Nicotine disrupts the normal course of blood circulation whereas pyrethrum does not.

Lethane, previously thought to be either a nerve or muscle poison, has a profound and rapid depressing effect on heart pulsations and blood circulation, followed by recovery or an approach to recovery,—an effect characteristic of HCN and unlike that of pyrethrum and nicotine. As HCN is a respiratory poison and as *Lethane* is chemically related to it, the latter may also act in part as a respiratory poison.—9-12-44.

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Time Schedules for Grasshopper Surveys in Arizona

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In Arizona accurate grasshopper surveys are practically impossible without the use of time schedules based on the seasonal histories of important economic species in different agricultural areas of the State. Owing largely to great differences in elevation, the climate in different parts of Arizona varies widely. For example, the length of the growing season averages about 4 months at Flagstaff, and 11 months at Yuma. Consequently, there are wide variations in the seasonal history of grasshoppers in different areas and of different species in the same locality. One of the most important grasshopper species in Arizona, the lesser migratory grasshopper, *Melanoplus mexicanus* Sauss., hatches approximately 2 months earlier at Tempe and Yuma than at Flagstaff. At both Tempe and Yuma the multiple-brooded *M. mexicanus* hatches 6 to 8 weeks earlier than the single-brooded *M. differentialis* (Thos.), another important species, particularly in the southern part of the State. At Flagstaff *M. mexianus* is essentially one-brooded, but at Chino Valley there are two broods per year, and at Yuma three broods per year. These examples are deemed sufficient to indicate the complexity of the seasonal history in Arizona and the need for survey schedules covering the different species in the different areas.

The purpose of this paper is to furnish information regarding the average dates of important events in the seasonal histories of grasshopper species in different areas and to suggest the most probable dates for making efficient surveys. It is hoped that this information may be of immediate practical value to persons and agencies responsible for grasshopper control programs in Arizona. It is based on 8 years of observations, 1936 to 43 incl., on the seasonal histories of leading economic

[1] The writer wishes to thank C. M. Packard and V. L. Wildermuth, under whose direction this work was done, for valuable suggestions and criticism of the manuscript. Much credit is due J. R. Parker, R. L. Shotwell, and E. G. Davis for information and advice concerning methods of making grasshopper observations and surveys. Determinations of the different grasshopper species by A. B. Gurney and the late E. D. Ball were highly appreciated.

species of grasshoppers in representative habitats and areas of Yuma, Maricopa, Yavapai, and Coconino Counties. In 1943 these four counties had 570,080 acres of cultivated land, or 57.9 per cent of the 984,890 acres of cultivated land in Arizona. By adding the 220,500 acres of cultivated land in Pinal County, where the climate, topography, crops, and dominant grasshopper species in the main agricultural districts are very similar to those in Maricopa County, the area represented is raised to 80.3 per cent of the total for the State. The observations were made at locations representative of the wide range of climate in the leading agricultural areas of the state.

Since grasshopper investigations were conducted in several widely separated areas, it was impracticable in most cases to ascertain the exact dates of the various seasonal-history events. These dates were estimated on the basis of the stage or stages of development observed at the time of periodic visits to the areas. During the active grasshopper seasons of 1936 and 1937 visits were usually made at intervals of 2 weeks. In 1938 the interval was lengthened to 3 weeks. After getting a rough idea of the seasonal histories of leading species in the different areas, visits were timed to coincide as closely as possible with important events in the seasonal history. Although the data obtained in this way are not precise, it is believed that they are accurate enough for practical purposes.

Eight years is not long enough for a thorough study of the seasonal histories of important economic grasshopper species in all the important agricultural areas of Arizona. During an 8-year period some species may be numerous and dominant for a few years, then decline almost to the vanishing point. Other species, with very low initial populations, may increase rapidly, become dominant, and cause outbreaks. As a result, fully dependable observations on the seasonal history of a particular species may be made in only a few of the years in a fairly long period. There is the further disadvantage that, owing to variable populations of different species in the same area, the most accurate observations of the seasonal histories of different species cannot always be made during the same year or years, making direct comparisons of specific responses to identical weather conditions impossible. It is also probable that some species that were present in small numbers throughout the period from 1936 to 1943 may increase to outbreak proportions in future years. Continued observations will undoubtedly reveal further variations and irregularities in seasonal histories, and average seasonal-history summaries and survey schedules will have to be altered accordingly. In the meantime, it is thought that the information already obtained, although representing only 8 years of study, should be made available to those interested in grasshopper surveys and control, especially at this time, when it is necessary to utilize all our resources for the saving of food products.

A pertinent question which arises, when calculating average dates of seasonal-history events and suggesting survey dates, is: What is the yearly variation in the seasonal history of all species in a given locality or area? Over a period of 8 years the variation in the first hatching date of dominant species was 16 days at Yuma, 26 days at Tempe, 20 days at Chino Valley, and 31 days at Black Bill Park, near Flagstaff. During the same period the variation in the date of first adult appearance was 12 days at Yuma, 14 days at Tempe, 23 days at Chino Valley, and 35 days at Black Bill Park. Obviously, if survey-schedule dates based on average dates of seasonal-history events were always strictly followed, there would be years when the surveyor would miss the optimum time for a survey in some localities by 15 days or more. If the season is unusually early or unusually late, such information can be gotten from weather observers or county agents, and the survey dates can be advanced or delayed to conform with the growth of vegetation and development of the grasshoppers. Schedules based on average dates, although imperfect, do have definite value. They point out what species to look for, and where and approximately when to look for them. Without the use of schedules, a surveyor unfamiliar with the seasonal histories of Arizona grasshoppers might miss important species in some localities and entire broods of some species in other localities.

Ready comparisons may be made from the descriptive data and information shown in table 1, on the physical and climatic features of typical areas and ob-

Table 1.—Description of typical areas in which seasonal-history observations on grasshoppers were made, 1936–43.*

AREA	COUNTY	APPROXIMATE ELEVATION	MEAN TEMPERATURE	ANNUAL RAINFALL	AVERAGE GROWING SEASON
		Feet	*°F.*	*Inches*	*Days*
South Gila[1] Valley, near Yuma	Yuma	150	71.9	3.62	332
Salt River[1] Valley, near Tempe	Maricopa	1100	68.6	8.05	282
Verde Valley,[1] near Cottonwood and Bridgeport	Yavapai	3400	63.3	11.29	229
Peeples Valley[2]	Yavapai	4500	56.8	20.00	198
Chino Valley[1]	Yavapai	4600	56.5	13.35	192
Prescott[1]	Yavapai	5000	52.9	20.52	144
Black Hill[3] Park, near Flagstaff	Coconino	6800	45.7	22.80	123

[1] Irrigated.
[2] Some very small fields irrigated.
[3] Not irrigated.
* The data given in this table may be considered as only approximately representing the actual conditions in the various areas. Elevation above sea level is given in round numbers, because it varies considerably at different points within the different areas. Temperature and rainfall data were taken from Weather Bureau reports or from records made by special observers. Some of the weather records were made within the areas where intensive grasshopper investigations were in progress, but most of the data were obtained from records made at established weather stations from 2 to 13 miles distant from the areas and at similar elevations.

servation stations where the seasonal histories of Arizona grasshoppers have been observed during the 8-year period 1936–43. Supplementary observations were made at several places not listed in the table, notably at Roll and in the Yuma Valley in Yuma County, Theba in Maricopa County, and Big Park and Williamson Valley in Yavapai County. In table 2 certain events in the seasonal histories of important grasshopper species are summarized, and proposed dates for making nymphal, adult, and egg suveys are given for each species or major hatching brood in each county or important agricultural area covered in this paper. No egg-survey dates are given, however, for any but the last brood of any one of the multiple-brooded species.

COMBINING SURVEYS OF DIFFERENT SPECIES.—In making an actual grasshopper survey of the areas discussed in this paper it would not usually be necessary to make all the surveys of the individual species listed in table 2. If it is assumed that both *Melanoplus mexicanus* and *M. differentialis* were abundant enough to justify a survey in the same year in Yuma County, it would be necessary to make a nymphal survey of the spring brood of *M. mexicanus* April 5 to 15, before the main hatching period of *M. differentialis* has begun. The suggested time for the adult survey of the spring brood of *M. mexicanus* is May 20 to 30, whereas that for the nymphal survey of the single brood of *M. differentialis* is June 1 to 10. Under such circumstances the adult survey of the spring brood of *M. mexicanus* and the nymphal survey of the single brood of *M. differentialis* might be combined and made very late in May or very early in June. Further, the adult survey of the single brood of *M. differentialis* is listed for July 15 to 25, and the nymphal survey of the second or summer brood of *M. mexicanus* for July 5 to 15. These two surveys could be combined and made about July 10 to 20. The same method of procedure would apply in making surveys of *M. mexicanus* and *M. differentialis* in Maricopa County, and could probably be used in making surveys of these species in Pinal and other counties.

By only a slight rearrangement of dates, the adult survey of the first or spring brood of *Melanoplus mexicanus* and the nymphal survey of the single brood of *M. femur-rubrum* (Deg.) can be made together in the Verde Valley area of Yavapai County. In the Chino Valley area of the same county the developmental periods of the second brood of *M. mexicanus* and the single brood of *M. lakinus* Scudd. coincide so closely that surveys of the two species may be made at the same time. Except during periods when there are outbreaks of *Dissosteira carolina* (L.), a late hatching species, it seems probable that general surveys in the high plateau country of Coconino County should be timed to fit *M. mexicanus* and *M. packardii* Scudd., which are species with somewhat similar seasonal histories and intermediate between the extremely early- and the extremely late-hatching species.

Table 2.—Average dates of seasonal-history events and recommended survey schedules for important grasshopper species in four Arizona counties.

SPECIES, AND BROOD	HATCHING PERIOD	NYMPHAL PEAK	NYMPHAL SURVEY	FIRST ADULTS	MAJORITY ADULT	ADULT SURVEY	EGG SURVEY
Melanoplus mexicanus			*South Gila Valley*				
1st brood	Feb. 24–May 4	Apr. 14	Apr. 5–14–15	Apr. 16	May 21	May 20–30	—
2nd brood	June 10–July 14	July 9	July 5–15	July 12	July 30	Aug. 1–10	—
3rd brood	Sept. 10–Oct. 27	Oct. 17	Oct. 10–20	Oct. 17	Nov. 13	Nov. 15–25	Dec.
M. differentialis							
Only brood	Apr. 22–June 8	June 4	June 1–10	June 21	July 15	July 15–25	Nov.–Dec.
			Salt River Valley				
M. mexicanus							
1st brood	Feb. 24–May 2	Apr. 23	Apr. 15–25	Apr. 25	May 27	June 1–10	—
2nd brood	June 16–July 20	July 15	July 10–20	July 20	Aug. 12	Aug. 10–20	Dec.
M. differentialis							
Only brood	Apr. 9–June 8	May 29	May 20–30	June 12	July 20	July 20–30	Nov.–Dec.
			Chino Valley				
M. mexicanus							
1st brood	Apr. 3–June 4	May 17	May 10–20	May 23	June 22	June 20–30	—
2nd brood	July 13–Sept. 15	Aug. 20	Aug. 15–25	Aug. 22	Oct. 3	Oct. 1–10	Nov.
M. lakinus							
Only brood	July 3–Aug. 25	Aug. 16	Aug. 10–20	Aug. 16	Sept. 18	Sept. 20–30	Nov.
			Peeples Valley				
M. mexicanus							
1st brood	Apr. 4–May 15	May 14	May 10–20	May 17	June 13	June 15–25	—
2nd brood	July 18–Aug. 25	Aug. 23	Aug. 15–25	Aug. 30	Sept. 28	Oct. 1–10	Nov.
M. differentialis							
Only brood	May 30–July 25	July 21	July 20–30	July 30	Aug. 28	Sept. 1–10	Nov.
M. femur-rubrum							
Only brood	May 12–July 11	July 5	July 1–10	July 8	Aug. 16	Aug. 15–25	Nov.
			Prescott				
M. femur-rubrum							
Only brood	May 15–July 12	July 10	July 5–15	July 12	Aug. 27	Aug. 25–Sept. 5	Nov.
			Verde Valley				
M. mexicanus							
1st brood	Mar. 15–May 5	Apr. 29	Apr. 25–May 5	May 5	June 15	June 15–25	—
2nd brood	July 15–Aug. 25	Aug. 20	Aug. 15–25	Aug. 22	Sept. 13	Sept. 10–20	Nov.
M. differentialis							
Only brood	May 14–July 12	July 12	July 10–20	July 24	Sept. 1	Sept. 1–10	Nov.
M. femur-rubrum							
Only brood	Apr. 17–July 17	July 2	June 25–July 5	July 1	Aug. 22	Aug. 20–30	Nov.
			Black Bill Park				
M. mexicanus							
Only brood	Apr. 24–June 3	May 28	May 25–June 5	June 6	July 7	July 10–20	Late Sept.–Oct.

Table 2.—Average dates of seasonal-history events and recommended survey schedules for important grasshopper species in four Arizona counties—(continued).

SPECIES, AND BROOD	HATCHING PERIOD	NYMPHAL PEAK	NYMPHAL SURVEY	FIRST ADULTS	MAJORITY ADULT	ADULT SURVEY	EGG SURVEY
M. occidentalis							
Only brood	Apr. 21–May 22	May 22	May 20–30	June 5	June 27	July 1–10	Late Sept.–Oct.
M. packardii							
Only brood	May 1–June 14	June 7	June 5–15	June 15	July 17	July 15–25	Late Sept.–Oct.
Dissosteira carolina							
Only brood	May 13–June 26	June 19	June 15–25	June 30	July 22	July 22–30	Late Sept.–Oct.

VALUE OF REPORTS IN PLANNING SURVEYS.—Where seasonal histories of grasshoppers vary greatly between species and from area to area, as in Arizona, much time can be saved in making general surveys by reviewing the survey reports of preceding years. These reports show the counties or agricultural areas in which economic infestations of grasshoppers exist. They also show the leading or dominant species in each county or area. With this information available, the general survey could be limited to infested areas and timed to suit the seasonal history or histories of dominant species in each of these areas. For example, *Melanoplus differentialis* was of little or no consequence in the Roll-Wellton and Yuma Valley areas of Yuma County for 7 successive years, 1936–42. In the South Gila Valley area of the same county, however, there were light-to-severe infestations of *M. differentialis* in several fields in different years during the 1936–42 period. Until there is a change in the distribution pattern of *M. differentialis* in Yuma County, it is believed that special annual surveys for that species are unnecessary in the Roll-Wellton and Yuma Valley areas but should be made each year in the South Gila Valley.

The status of *Melanoplus mexicanus* in Yuma County is quite different from that of *M. differentialis*. Economic infestations of *M. mexicanus* have been distributed over all the main agricultural districts of the county. Light-to-severe infestations have occurred in all major districts under observation in two or more years during the period from 1936–43, the infestations being lighter in the Yuma Valley area than in the Roll-Wellton and South Gila Valley areas. As *M. mexicanus* has three broods each year and consequently a very high capacity for increase in numbers from one year to the next in Yuma County, and because of its observed ability to decline and reappear in threatening numbers several times within a period of 8 years, it would probably be a good practice to make at least some of the surveys recommended for this species in all the agricultural districts of the county each year, regardless of the population status the preceding year. Annual surveys of *M. mexicanus* would also reveal any localities where *M differentialis* populations are increasing and should receive more attention.

Observations at Chino Valley from 1936 to 1943 furnish another good example of how the time required for making grasshopper surveys may be reduced by a thorough knowledge of recent conditions in an area. During that period two species, *Melanoplus lakinus* and *M. mexicanus*, have been dominant in the area. For 4 years, 1936–39, *M. lakinus* was overwhelmingly dominant, while the *M. mexicanus* population was insignificant. *M. mexicanus* increased rapidly in 1940, however, and by the fall of that year had become dominant, and *M. lakinus* was lagging far behind. *M. mexicanus* has continued to be the dominant species in 1941, 1942, and 1943, the numbers of *M. lakinus* being of no consequence. The general grasshopper population was high enough in some fields to be of economic importance each year from 1936 to the spring of 1942, but it fell to an extremely low point late in the summer and in the fall of 1942 and remained very low throughout 1943. There was no need of grasshopper surveys at Chino Valley during the spring and early summer of the years when *M. lakinus* was dominant and the only important species in the area, because *M. laki-*

nus has only one brood a year and hatches mainly in July and August. The surveys from 1936 to 1940, during the 1936–39 period when *M. lakinus* was dominant and for 1 year thereafter, until it became evident that *M. lakinus* had declined to an inconsequential status, should have been made in mid-August, late in September, and in November, as recommended in the schedule for that species.

After *Melanoplus mexicanus* became dominant it was necessary to increase the number of annual surveys because this species has both a spring brood and a late summer-early fall brood at Chino Valley. The very low populations found late in the summer and in the fall of 1942 were indicative of the low populations that followed in 1943. From the practical standpoint of grasshopper control, it seems unnecessary to make all the recommended surveys when the survey of the previous year indicates a very low population. A single survey in mid-August or very late in September should be sufficient to determine whether there has been a substantial change in the population. It seems justifiable to repeat that the seasonal history of the fall or second brood of *M. mexicanus* coincides very closely with the seasonal history of the single brood of *M. lakinus* at Chino Valley. Apparently, it will always be possible to check the population levels of both these species by surveys timed primarily for either of them. Nymphal or adult surveys, or both, should be made of the spring brood of *M. mexicanus* when late-summer and fall surveys indicate that it is gaining rapidly in numbers after a low point in its abundance cycle or that its population is high enough to be of economic importance.

SEASONAL HISTORY VARIATIONS.—The seasonal histories of grasshoppers in Arizona are influenced to a considerable extent by rainfall and irrigation practices. As a result, time schedules for making grasshopper surveys do not always apply under all conditions encountered in an area. They do apply remarkably well, however, to one-brooded species that hatch in the spring, and to the spring brood of multiple-brooded species. The greatest difficulties come with second and third broods of multiple-brooded species and with species having but a single brood that hatches late in the summer and in the fall.

The effects of rainfall and irrigation practices on the seasonal history of a multiple-brooded species can be well illustrated with *Melanoplus mexicanus* in Yuma County. Alfalfa is the leading crop susceptible to grasshoppers. It is grown principally for seed production, and requires irrigation. In alfalfa fields there are usually three broods of *M. mexicanus* each year. There are always two broods when the soil is kept moist by the use of irrigation water until midsummer, when the first crop of alfalfa seed is maturing. If irrigation water is applied to the land after the harvest of the first seed crop, there is a third brood late in the summer or early in the fall. If irrigation water is withheld late in the summer and early in the fall, and if there is no substantial amount of rainfall during that period, the third brood does not appear. A third brood will follow heavy August rains even when no irrigation is given. In the South Gila Valley the practice is to delay the first irrigation following the harvest of the first alfalfa seed crop until very late in the summer or early in the fall. Usually this irrigation is made during the period from very late in August to very early in October, the date varying somewhat from field to field and from year to year. Hatching of the third brood begins soon after the soil is thoroughly moistened, in most years between September 1 and 25. In the Roll district the soil is generally kept fairly moist throughout the growing season, except while the seed crops are maturing and being harvested. Irrigation follows almost immediately after the seed harvest, and the third brood starts hatching in August, sometimes as early as August 5 to 10. Under certain conditions late in the summer and in the fall, hatching may consist of two distinct hatches or broods. Hatching may begin following heavy rains early in August, stop when the top soil becomes dry again, and then be resumed after the first fall irrigation in September or early in October. Obviously, efficient surveys of late-summer- and fall-hatching broods of *M. mexicanus* in Yuma County depend largely on a knowledge of current rainfall and of prevailing irrigation schedules.

In Maricopa County the third brood of *Melanoplus mexicanus* has been of little importance—hardly of sufficient magnitude to justify a separate survey for that

brood. In most years there is a very light third brood, and in one of the 8 years during which investigations were made no third-brood hoppers were observed. As in Yuma County, the time of hatching of the third brood depends to a considerable extent on the irrigation dates during the latter part of the summer and the fall, and usually begins between September 5 and the early part of October. In 1943 hatching began unusually early, about August 20, following very heavy rains early in August.

The amount and distribution of rainfall during June and the early part of July affect the seasonal history of some grasshopper species in Yavapai County. At Chino Valley the hatching period of the single brood of *Melanoplus lakinus* began 8 to 20 days earlier in years when the June rainfall exceeded 1 inch than in years when it ranged between a trace and 0.32 inch. The second brood of *M. mexicanus* hatched 15 to 20 days earlier when the June rainfall was 1.39 inches than when it ranged between zero and 0.32 inch. These observations were somewhat surprising, because rainfall is supplemented by irrigation in some of the leading grasshopper habitats. It should be explained, however, that during the period 1936–43 there was usually an insufficient amount of irrigation water to meet the needs of the agricultural acreage at Chino Valley.

Another instance of seasonal-history differences apparently due to rainfall and irrigation practices can be given for Yavapai County. Chino Valley and Peeples Valley are about 45 miles apart, both have approximately the same elevation above sea level, and the mean temperature is almost identical at the two locations. As mentioned previously, irrigation supplements rainfall at Chino Valley. Rainfall is the only source of soil moisture at Peeples Valley, except for a few home gardens, truck patches, and small plots of alfalfa, which are irrigated from wells. Rainfall records at Yarnell, only 4 miles away from Peeples Valley, suggest the probability that the rainfall at Peeples Valley is somewhat higher than at Chino Valley. As shown in table 2, the average hatching period of *Melanoplus mexicanus* is longer in the irrigated Chino Valley area than in the closely similar but unirrigated Peeples Valley area, and the second brood of that species hatches later in the unirrigated area than in the irrigated one. The average date of first hatching of the first brood is approximately the same in the two areas, April 3 or 4. Hatching continues for 62 days at Chino Valley but lasts only 42 days at Peeples Valley. On the average, hatching of the second brood begins 5 days later at Peeples Valley than at Chino Valley. The hatching period lasted 64 days at Chino Valley and less than 41 days at Peeples Valley. It seems probable that additional soil moisture in the irrigated land at Chino Valley causes a denser growth of vegetation, and consequently a more shaded and cooler soil, than is the case in unirrigated land. The cooler soil probably retards egg development in such habitats as alfalfa, so that the hatching period is prolonged. Notwithstanding these differences in the seasonal history of *M. mexicanus* at Chino Valley and at Peeples Valley, a survey timed for this species at either location might well be extended to the other, and reasonably adequate observations might be made.

KEY HABITATS AND PARTIAL SURVEYS.—The results of 8 years of intensive observations on representative areas suggest that under certain conditions it might be impractical or unnecessary to make complete State or county grasshopper surveys every year. Nevertheless, an annual check of populations in favored habitats of areas where outbreaks are known to occur seems desirable. In Yuma, Maricopa, and Pinal Counties the examination of a few scattered alfalfa fields and field margins in the principal agricultural districts would generally be sufficient to determine whether populations were at a very low ebb or high enough to warrant a more thorough and detailed survey. Favored habitats in Yavapai County are alfalfa, weedy field margins, small grain, and weedy idle land. In Coconino County favored habitats are similar to those in Yavapai County, although alfalfa is of less importance, and untimbered pasture land within or adjacent to cultivated areas should be included. —8-26-44.

Some Effects of Phenothiazine, Phenothiazone and Thionol on *Periplaneta americana*[1]

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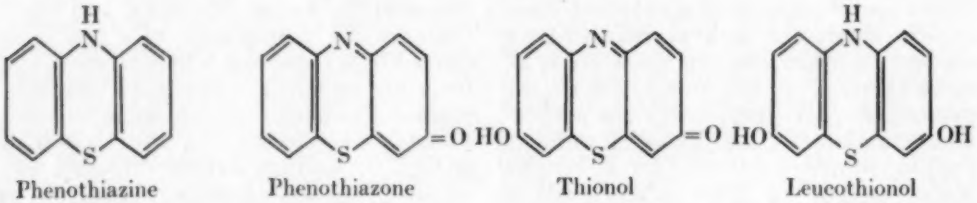
Phenothiazine has been extensively studied since its discovery as an insecticide in 1934. The compound approaches the specifications for an ideal insecticide by its high toxicity to some insects, by its low toxicity to humans and to other vertebrate animals; and by the absence of foliage injury and spray residue (Fahey & Rusk 1940). A promising fungicidal action has also been reported (Goldsworthy & Green 1939, Roberts 1942). The compound can be prepared easily for insecticidal use (Smith 1938), and it has been assigned to free use in the United States by the patentee (Gaylor 1940).

A drawback to the general use of phenothiazine, however, is its variable action against some insects. The investigation reported was undertaken with the hope that a detailed study of the internal action of phenothiazine and its two oxidation products, phenothiazone and thionol, against one insect might suggest the cause of the variable insecticidal action. A preliminary note on the effect of phenothiazine upon *Periplaneta americana* (L.) has already appeared (Zukel 1942).

The structural relationships of phenothiazine, phenothiazone, thionol and leucothionol are shown in the following formulae.



Phenothiazine — Phenothiazone — Thionol — Leucothionol

Phenothiazine was first prepared by the fusion of diphenylamine with sulfur by Bernthsen (1883). The synthesis was improved upon with a catalyst, resulting in a quantitative yield requiring no purification for insecticidal use (Smith 1938). Phenothiazine crystallizes from alcohol as colorless, diamond-shaped plates, moderately soluble in fat solvents and insoluble in water (Bernthsen 1885). The melting point is 185.11° C. (Smith & Nelson 1942). The compound undergoes oxidation to phenothiazone on exposure to sunlight (Goldsworthy & Green 1939). Mixing it with a finely divided inert carrier results in a spontaneous oxidation to thionol (DeEds 1940).

Phenothiazone is prepared by the oxidation of phenothiazine, resulting in reddish-brown leaflets which are soluble in alcohol and only slightly soluble in water. The melting point is 162° C. (Pummerer & Gassner 1913).

Thionol is prepared by the oxidation of phenothiazine with sulfuric acid (Bernthsen 1885), or with hydrogen peroxide (DeEds & Eddy 1938). It is a tarry compound with no definite melting point, difficultly soluble in water but soluble in alkalis and in alcohol. The potential of the oxidation-reduction system, thionol-leucothionol, was determined by DeEds & Eddy (1938).

The insecticidal property of phenothiazine was discovered by Campbell *et al.* (1934) who found that one part per million parts of water was toxic to mosquito larvae. Later experiments proved the compound to be toxic to a number of economically important insects. Siegler *et al.* (1936) reported phenothiazine to be equal in toxicity to lead arsenate against codling moth larvae, *Carpocapsa pomonella* (L.),

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[3] Now with the U. S. Public Health Service.

under laboratory conditions. Bruce (1939) fed cattle 22.0 milligrams of phenothiazine per kilogram of body weight to prevent the development of horn fly larvae, *Haematobia irritans* (L.). Lennox (1940) reported that 0.01 per cent of phenothiazine in an artificial medium was toxic to larvae of the blow fly *Lucilia cuprina* and Bushland (1940) found that 0.05 per cent phenothiazine in a food mixture was toxic to screwworm larvae, *Cochliomyia americana* C. & P. Mail (1936) and King (1938) reported that the addition of phenothiazine to petroleum oil increased the toxicity of the oil against culicine mosquito larvae. Further experiments have demonstrated that phenothiazine is effective against the European corn borer, *Pyrausta nubilalis* (Hbn.), (Batchelder *et al.* 1937); grape berry moth, *Polychrosis viteana* (Clemens), (Strong 1938); Mexican bean beetle, *Epilachna varivestis* Muls., (Howard *et al.* 1935); cherry fruit flies, *Rhagoletis cingulata* (Loew), *R. fausta* O. S., (Hamilton 1940); oriental fruit moth, *Laspeyresia molesta* (Busck), (Guy 1937); chicken lice, *Lipeurus heterographus* Nitzsch, *Eomencanthus stramineus* (Nitzsch), *Menopon gallinae* (L.), *Goniocotes hologaster* Nitzsch (Parish 1940); sheep maggot, *Lucilia sericata* (Meig.), (Hobson 1937); fleece worms, *Phormia regina* (Meig.), *Cochliomyia macellaria* (F.), *Lucilia sericata* (Meig.), (Knipling 1941); tomato fruit worm, *Heliothis armigera* (Hbn.), (Wilcox & Stone 1940); carrot weevil, *Listronotus latiusculus* (Boh.), (Pepper & Hagmann 1938); and tomato pinworm, *Gnorimoschema lycopersicella* Busck, (Thomas 1936).

Phenothiazine has been found to be ineffective against a number of insects. Hansberry & Richardson (1936) observed that a dosage of 1.12 milligrams per gram of body weight was not toxic to the larva of the cabbage butterfly, *Ascia rapae* (L.). Richardson & Seiferle (1939) reported that a dosage of 5.8 milligrams per gram of body weight was not toxic to the two-striped grasshopper, *Melanoplus bivittatus* (Say). Snipes *et al.* (1936) found that a 20.0 per cent mixture in food did not affect the firebrat, *Thermobia domestica* Pack. Bertholf & Pilson (1941) observed that phenothiazine had no effect upon the honey bee, *Apis mellifera* L., although as much as 570 micrograms were ingested. Phenothiazine has also proved ineffective against the cotton flea hopper, *Psallus seriatus* Reut., (Ewing & McGarr, 1937); European red mite, *Paratetranychus pilosus* (C. & F.) and plum curculio, *Conotrachelus nenuphar* (Hbst.), (Cutright 1937a); lesser migratory grasshopper, *Melanoplus mexicanus mexicanus* Saussure, (Richardson & Seiferle 1938); gladiolus thrips, *Taeniothrips simplex* Morison, (Smith 1943); and the cotton boll weevil, *Anthonomus grandis* Boheman, (Young & Smith 1936). A repellent effect against adults of the Japanese beetle *Popillia japonica* Newman, was reported by Dietz & Pierpont (1938) and by Guy & Schmitt (1937).

One of the main disadvantages of the use of phenothiazine as an insecticide has been its variable toxicity. Experiments against the codling moth varied in effectiveness from season to season (Strong 1937, 1938, 1939; Cutright 1937a, 1937b; Eyer 1938).The control of codling moth larvae has been termed satisfactory by some investigators (Harman and Reed 1937; Haseman *et al.* 1937; Guy 1937; Cutright 1937b and Bourne 1938), and entirely ineffective by others (Cutright 1937a, Webster & Marshal 1936, Webster *et al.* 1940). Phenothiazine was reported as ineffective against the European corn borer by Baker & Questel (1939), and as highly effective by Zappe *et al.* (1937) and Batchelder *et al.* (1937). Bushland (1940) found a pronounced difference in toxicity between five commercial samples of phenothiazine tested on screwworm larvae. A marked difference in toxicity between phenothiazine in dusts and sprays was reported by Batchelder *et al.* (1937) and by Wilcox & Stone (1940).

The cause of the variable action has not been fully explained. The particle size of the phenothiazine produced a difference in toxicity to codling moth larvae in laboratory experiments. Particles with an average diameter of 4 and 15 microns were more effective than particles of 45 microns in diameter (Siegler & Goodhue 1939). Phenothiazine in a fine particle size was found to be more effective against codling moth larvae under field conditions (Annand 1941). Bertholf & Pilson (1941) observed that the particle size produced no difference in results against the honey bee. Nelson & Smith (1942) found that the reduction in toxicity of phenothiazine several days after exposure under field conditions was not due to the vaporization of

the smaller particles. King (1938) reported that the undissolved phenothiazine was considerably less toxic to larvae of *Culex quinquefasciatus* Say than phenothiazine in an acetone solution.

Siegler (1940) added brown sugar and molasses to phenothiazine and noted an increased effectiveness of the mixture against codling moth larvae, while Siegler & Smith (1942) found that the addition of bentonite or hydrated lime decreased the effectiveness against the same insect. The fusion of diphenylamine with allotropic forms of sulfur did not account for a difference in toxicity to codling moth larvae in laboratory experiments (Siegler & Smith 1941). Steiner & Arnold (1943) reported a probable loss of toxicity of phenothiazine under relatively dry conditions. Knipling (1942) observed that screwworm larvae developed and transmitted a resistance to the toxic action of phenothiazine. In spite of its variable results phenothiazine remains a promising insecticide (Smith 1942).

Substitutes of the phenothiazine radical have been made in an effort to improve its toxicity. Lennox (1940) tested eight derivatives against blow fly larvae and concluded that substitutions on the radical did not improve the toxicity. Guy (1937) reported that phenothiazine was more effective than N-methyl phenothiazine against the Mexican bean beetle and Colorado potato beetle.

Experimental trials of the oxidation products of phenothiazine have been limited. Fink *et al.* (1938) reported that phenothiazone exhibited some toxicity to the larvae of *Culex quinquefasciatus* Say. No reference to the use of thionol as an insecticide was found in the literature.

Phenothiazine is valuable as an insecticide because of its very low toxicity to humans and to other vertebrate animals. Manson-Bahr (1940) reported experiments in which doses of 30 to 40 grams were administered to humans without apparent injury. DeEds *et al.* (1939) and Thomas *et al.* (1938) found that only a slight anemia developed when therapeutic doses were fed to humans. A photosensitivity from ingested phenothiazine was reported by DeEds *et al.* (1940) to be the cause of skin irritation among workmen who applied a phenothiazine spray. Horses, cows and sheep are extensively treated without injury with the compound for its anthelmintic effect (Britton 1941) Thomas *et al.* (1938) concluded that the use of phenothiazine as an insecticide introduced no public health hazard.

Investigations have been made in an effort to explain the action of phenothiazine and of its oxidation products upon the living organism. Woke (1940) found that the cells of the mid-intestine of the southern armyworm, *Prodenia eridania* (Cram.), which was killed by phenothiazine underwent no change in structure. Deonier & Lindquist (1942) believed that phenothiazine was toxic to the Clear Lake gnat, *Chaeborus asticopus* D. & S., by its action upon the nervous system.

Gersdorff & Claborn (1938) tested phenothiazine, phenothiazone and thionol against the goldfish. The authors found phenothiazone to be the most toxic and thionol to be only slightly toxic. They believed that the toxicity of phenothiazine resulted from oxidation to phenothiazone after absorption through the gills.

Collier (1940) observed that phenothiazine in a concentration of one part per ten million depressed the junctional transmission of nerve impulses in the shore crab, *Carcinus moenus*. Colllier & Allen (1942a) considered that the neuro-muscular block reported by Collier (1940) was probably a result of the oxidation product phenothiazone formed from the parent compound. Collier (1940a, 1940b) reported further that the free phenolic group of leucophenothiazone, leucothionol and thionol inhibited the respiratory enzyme, cytochrome oxidase. Collier & Allen (1942b) found that phenothiazone and thionol inhibited the enzyme, dehydrogenase; and attributed the action to the presence of free phenolic groups on the molecules. The same investigators (Collier & Allen 1942a) believed that the phenothiazine derivatives acted upon the nervous system through inhibition of the enzyme, cholinesterase, which is reported to mediate the nerve impulses at the synapse and neuro-muscular junction.

DeEds & Thomas (1941) suggested that the bactericidal, anthelmintic and insecticidal action of phenothiazine was due to an interference with the oxygen carrying systems by maintaining them in a permanently oxidized state.

MATERIALS AND METHODS.—Phenothiazine was prepared by crystallizing a commercial product three times from ben-

zene. The melting point was 184.0° C. Phenothiazone was prepared by the method of Pummerer & Gassner (1913). The melting point was 162.0° C. Thionol was prepared and purified as the hydrochloride according to the procedure given by Bernthsen (1885). The sodium salt was made by adding an equivalent amount of sodium carbonate to thionol. Pure starch was used as an inert carrier for the compounds.

Nymphs and adults of *Periplaneta americana* (L.) were collected from infested buildings in Ames, Iowa and Baton Rouge, Louisiana. They were confined to a cage with a food mixture[1] and water. Experiments were conducted upon both the wild insects and upon those which had been confined in cages for periods up to six months. A total of 1595 nymphs and adults were treated and dissected in the investigation.

The contact effect was determined after the preoral cavity was closed with a resin.[2] The resin was melted with a heated glass rod and a drop of the melt allowed to solidify between the mandibles of the insect. The bodies of the insects were dusted with the undiluted compounds and with a five per cent mixture in starch, or a saturated acetone solution of the compounds was applied to their abdomens.

Action within the alimentary canal was determined by allowing the insects to feed upon the compounds incorporated in food. The mixtures were placed in containers which prevented a contact effect during feeding. The results were verified by starving the insects for a week and allowing them to become satiated with a water suspension of the compounds applied to the mouthparts with a pipette.

Phenothiazine particles of varying size were prepared by crystallization and vaporization. The coarsest particles with mean diameter of 95 microns and a standard deviation of 52 microns were obtained by crystallization from alcohol. Particles of the intermediate and finest distribution were prepared by vaporizing phenothiazine into a closed cylinder. Caged insects were exposed to the phenothiazine cloud immediately after vaporization for the contact effect of the particles of intermediate size, having a mean diameter of 10 microns and standard deviation of 4.2 microns. Particles remaining suspended in air for approximately thirty minutes after vaporization were of the smallest size with a mean diameter of 3 microns and standard deviation of 1.1 microns.

All insects were dissected for chemical tests after contact, stomach and injection treatments. A drop of haemolymph was collected from the severed antennae. The head was then clipped off and the alimentary canal drawn out with forceps. The alimentary canal was separated into the foregut, mid-gut, hind-gut and Malpighian tubules. Qualitative micro-chemical tests of the separated parts were observed under a microscope.

Oxidation-reduction titration was carried on under carbon dioxide with crystalline titanous chloride prepared from the commercial solution by the method of Polidori (1899). The standard procedure of Clark *et al.* (1928) was employed.

Color reactions were relied upon to detect phenothiazine, phenothiazone and thionol because of the minute quantities available on the external surfaces and within the insect. The identification of the compounds formed in the alimentary canal and haemocele on the basis of the color reactions is tentative, and should be verified in further experiments by physical methods. The color reactions with saturated bromine water, concentrated sulfuric acid and with Bernthsen's phenothiazine test were used to detect phenothiazine. The reaction with saturated bromine water produces a red color reported by Eddy & DeEds (1937) to be 3,9-dihydroxyphenazothionium bromide. The resulting color varies in intensity with the phenothiazine concentration. The reaction was most reliable when an excess of bromine water was quickly added to the phenothiazine as suggested by Cupples (1942). An orange color reaction with concentrated sulfuric acid and a color test developed by Bernthsen (1883) were used as alternative tests for the detection of phenothiazine.

To carry out Bernthsen's phenothiazine test an excess of concentrated nitric acid was added to the material. The solution was diluted, acidified with hydrochloric acid and boiled with an excess of stannous chloride. Zinc was added to the solution which was then absorbed on filter paper. Exposure of the filter paper to ammonia

[1] Pablum, Mead Johnson and Co., Evansville, Indiana.
[2] Plicene, Central Scientific Company, Chicago, Illinois.

fumes produced a purple color. The test is sensitive to a fraction of a milligram of phenothiazine.

Phenothiazone crystals reacted with concentrated sulfuric acid to form a green color. The addition of an equal quantity of water converted the green color to red (Bernthsen 1885).

Thionol reacted with concentrated sulfuric acid and with dilute sodium hydroxide to form a blue color. The oxidation of leucothionol in air takes place slowly in an acidic solution and spontaneously in an alkaline solution (Bernthsen 1885).

The Folin-Ciocalteu phenol test (Folin & Ciocalteu 1927) was applied to the thionol conjugate present in the haemolymph. The insect was washed free of adhering phenothiazine particles with benzene. The dorsal surface was imbedded in wax and the ventral sclerites cut away. The haemocele was irrigated with a dilute sodium carbonate solution. The solution was then transferred to a separatory funnel, acidified and extracted with ether. The extract was separated from the solvent with a dilute solution of sodium carbonate and tested with the reagent by the standard procedure.

The most reliable test for the thionol conjugate in the haemolymph was the color reaction with concentrated sulfuric acid. A series of colors from a pink to a bright red and finally to a deep blue were produced, which varied in intensity with the concentration of the thionol conjugate dissolved in the haemolymph. The reliability of color as an index of the concentration was verified by comparing the series of colors with the intensity of the blue color formed with Folin-Ciocalteu reagent. In addition, pure thionol dissolved in the haemolymph *in vitro* gave the same series of colors with concentrated sulfuric acid. The most sensitive test was obtained by allowing the acid to flow into the drop of haemolymph, whereupon a concentrated band of color formed at the junction of the two liquids.

PHENOTHIAZINE AS STOMACH POISON.—Phenothiazine exhibited no toxicity when ingested by the insect. The compound was offered as a water suspension to starved insects and was fed in a food mixture. A total of 295 insects were treated and dissected to determine the action of phenothiazine as a stomach poison.

Phenothiazine administered as an aqueous suspension was readily ingested by the starved insects, filling the fore-gut with approximately 0.1 grams of the compound. Color tests with concentrated sulfuric acid, bromine water, and microscopic examination of the crystals indicated that phenothiazine usually remained unchanged in the fore-gut. In 3 of the 40 insects given the suspension, the phenothiazine was converted to an unknown blue-green compound. Phenothiazine had been retained in the fore-gut for three or more days by these insects.

Phenothiazine crystals could be detected in the small amounts of material passed by the proventriculus through the mid-gut.

The hind-gut contained free phenothiazine crystals suspended in a gray semi-fluid residue, which slowly turned red in air. The change was rapid in the presence of ammonia fumes. The dry residue reacted with alkali and with concentrated sulfuric acid to form a blue color. The color tests indicated that the hind-gut contained free phenothiazine crystals and leucothionol in solution.

The haemolymph and Malpighian tubules gave negative tests for phenothiazine and for its related products when subjected to concentrated sulfuric acid, bromine water and to Bernthsen's phenothiazine test.

Phenothiazine was administered in different foods. A total of 40 insects readily ate a food mixture containing 5 per cent phenothiazine by weight over a period of two months without apparent injury. During normal feeding the amount of phenothiazine stored in the fore-gut formed only a fraction of the amount ingested as a suspension by the starved insects. No change in the phenothiazine in the fore-gut was observed and no phenothiazine could be detected in the mid-gut. Likewise phenothiazine was usually absent from the hind-gut. The contents of the hind-gut gave the tests for leucothionol as reported for the starved insects after ingesting a water suspension of phenothiazine. The haemolymph and Malpighian tubules gave negative tests with concentrated sulfuric acid, bromine water and with Bernthsen's phenothiazine test.

A total of 215 insects were dissected

after feeding upon phenothiazine mixed with different foods and salts. Insects were allowed to feed upon a 20 per cent mixture of phenothiazine incorporated in casein, sucrose, dextrose, starch and gelatin. Other insects were also allowed to feed upon three preparations made up of phenothiazine 20 per cent, food mixture 60 per cent; to which potassium chloride, sodium chloride and potassium nitrate were added to make up the balance.

No difference in toxicity was observed between insects remaining on the untreated food mixture[1] and those ingesting the phenothiazine mixture. The distribution of the phenothiazine in the alimentary canal and the conversion of phenothiazine to leucothionol was the same as that observed in the insects which fed for an extended period on 5 per cent phenothiazine mixture.

PHENOTHIAZINE AS A CONTACT POISON.—Phenothiazine is toxic as a contact insecticide. The internal concentration of the leucothionol conjugate that is present in the haemolymph is reflected in the behavior of the insect. The insect either succumbed, exhibited uncoordinated walking movements and recovered or appeared to be unaffected. The insect always died when the haemolymph gave a blue reaction with concentrated sulfuric acid; and died or exhibited uncoordinated walking movements and recovered when a red reaction resulted.

Under optimum condition of application, death resulted in approximately 24 hours. A lack of coordination in walking, evident in about 5 hours, was the first visible effect of phenothiazine. This symptom gradually became more pronounced, and in approximately 18 hours the insect usually fell on its back and responded to tactile stimuli only by moving the appendages. This condition persisted until death.

A total of 745 insects were dissected in the study of phenothiazine as a contact insecticide.

The internal condition after a lethal surface dosage of phenothiazine was determined. A lethal surface dosage was produced on 280 of the 745 insects treated for the contact effect of phenothiazine. Upon dissection of an insect killed by phenothiazine, the bright red color of the Malpighian tubules was visible to the naked eye. Examination under magnification usually disclosed the presence of irregularly-shaped, pale yellow and red crystals; in addition to a red fluid dispersed through the lumen. Exposure to air or to an oxidizing agent converted the pale yellow crystals to a red compound soluble in the fluid of the Malpighian tubules. The contents of the tubules dissolved in alkali to form a red color, and gave a positive test for the phenol radical with Folin-Ciocalteu reagent. A negative test for phenothiazine was obtained with saturated bromine water and with Bernthsen's phenothiazine test. A blue color developed with concentrated sulfuric acid. The yellow crystals slowly dissolved in constant boiling hydrochloric acid to give a greenish-blue color at the periphery of the crystal. The reaction with concentrated nitric acid produced a red color.

The yellow crystals are believed to be a conjugate of thionol of unknown chemical composition, present in leuco form, and the red crystals the oxidized form of the conjugate. The crystals are not thionol itself for the pure compound forms a blue color with alkali and is not crystalline. The color reactions with concentrated sulfuric acid and nitric acid, and the color resulting after hydrolysis with hydrochloric acid, were identical with those given by pure thionol. Attempts to identify the thionol of the Malpighian tubules resulting from the hydrolysis with hydrochloric acid by oxidation-reduction titration with titanous chloride (DeEds & Eddy 1938) were unsuccessful because of the small amounts available.

The haemolymph of insects killed with phenothiazine is usually colorless, but upon exposure to the air it generally becomes a deep red in color. The haemolymph gave a negative test with Bernthsen's phenothiazine test, and a blue color developed on addition of concentrated sulfuric acid. The compound dissolved in the haemolymph responded to the tests for the leucothionol conjugate of the Malpighian tubules.

The contents of the fore-gut and the mid-gut gave negative tests for phenothiazine and for the thionol conjugate. The contents of the hind-gut were usually gray in color. Exposure to air or to an oxidizing agent converted the gray color to red, the change being rapid in the pres-

ence of ammonia fumes. Tests for phenothiazine were negative. The addition of concentrated sulfuric acid to the dried contents of the hind-gut produced a blue color. The color reactions indicated that the hind-gut contained a leucothionol compound.

The internal condition after a sublethal surface dosage was observed on 170 of the 745 insects treated for the contact effect of phenothiazine. The internal concentration of the thionol conjugate in the insect, which showed an uncoordinated walk and recovered, differed from that reported for the dead insect. The symptom varied in intensity and in duration, often persisting for five days before the insect recovered. Usually the haemolymph did not change color on exposure to air. The test with concentrated sulfuric acid produced a varied intensity of red, but in no case was the concentration of the leucothionol conjugate in the haemolymph sufficient to produce a blue color with the acid.

The lumen of the Malpighian tubules usually contained only the pale crystals of the leucothionol conjugate. The number of the crystals present in the lumen varied directly with the time the phenothiazine remained in contact with the cuticle.

The contents of the hind-gut responded to the same tests recorded for the dead insect which succumbed to the contact action of phenothiazine. No phenothiazine or thionol was detected in the fore-gut or mid-gut.

The remainder, or 295 insects, showed no visible effects from the phenothiazine in contact with the cuticle. The concentration of the leucothionol conjugate in the haemolymph of these insects was too low to be detected with concentrated sulfuric acid. The conjugate however was present in the haemolymph for the Malpighian tubules contained crystals of the leucothionol conjugate. The number of crystals present varied directly with the length of time the phenothiazine remained in contact with the cuticle. The reactions of the alimentary canal were identical with those reported for insects which succumbed to the contact action of phenothiazine.

The effect of the particle size of phenothiazine upon the contact action was observed on 295 insects that were dissected. The quantity and the particle size of the phenothiazine in contact with the cuticle produced the varied toxicity. The amount of phenothiazine in contact was visually estimated by observing the intensity of color after treating the cuticle with saturated bromine water. Large, intermediate and fine particle sizes of phenothiazine were used.

The finest particles with a mean diameter of 3 microns produced the most rapid kill with the least quantity in contact with the cuticle. If a sufficient amount of the fine particles was placed in contact with the cuticle, the haemolymph concentration of the leucothionol conjugate reached a red or deep blue color to concentrated sulfuric acid from 24 to 48 hours after exposure. The phenothiazine particles in contact with the cuticle were not visible to the naked eye, but were detected after treatment with bromine water.

If the insects were exposed to the fine particles for too short a time, the quantity of phenothiazine in contact with the cuticle was not sufficient to produce a lethal concentration of the leucothionol conjugate in the haemolymph. Under these conditions the insect either showed no symptoms, or developed an uncoordinated walk and recovered.

Phenothiazine particles of the intermediate range with a mean diameter of 10.0 microns killed the insect slowly, provided a sufficient amount was in contact with the cuticle. Death did not usually take place until two to five days after treatment. Sampling and treating the haemolymph drawn from the antennae showed a progressive increase in the concentration of the leucothionol conjugate as the insect gradually succumbed to the compound. The dosage of phenothiazine of intermediate particle size required to kill the insect was much greater than the dosage of the fine particles, as determined by the intensity of color resulting from treatment of the cuticle with bromine water.

If the amount of phenothiazine in contact was insufficient to produce a lethal concentration of the conjugate in the haemolymph, the insect showed the characteristic uncoordinated walk and recovered; or was visibly unaffected.

Coarse phenothiazine crystals with a mean diameter of 95 microns, or large

crystals formed by applying a saturated acetone solution, did not usually kill the insect unless the body was liberally covered with the compound. With a sub-lethal dosage the insect either maintained uncoordinated walking movements, or was visibly unaffected by the large quantity of phenothiazine in contact with the cuticle.

Phenothiazine was injected into a total of 125 insects. The compound, suspended in water by evaporating an alcohol solution, was injected directly into the haemocele. No feasible method of measuring accurately the amount introduced was discovered. Approximately one drop of water containing particles which remained suspended under rapid agitation was introduced into each insect.

If a sufficient amount of phenothiazine was injected, the insect died in approximately 24 hours. The haemolymph gave a deep red or blue reaction to concentrated sulfuric acid, and the Malpighian tubules were red with the oxidized form of the thionol conjugate.

The injection of a sub-lethal amount of phenothiazine produced the characteristic uncoordinated walking movements, and the insect recovered. The haemolymph then usually gave a light red color reaction with sulfuric acid and the Malpighian tubules contained the yellow crystals of the leucothionol conjugate.

The observations of the alimentary canal were the same as those recorded for the insect killed by contact with phenothiazine.

EFFECT OF PHENOTHIAZONE.—Phenothiazone taken into the alimentary canal was not toxic to the insect. No change in the compound was observed in the fore-gut of the 60 insects dissected. Phenothiazone was converted to a compound responding to the color tests for leucothionol during passage through the mid-gut. The contents of the hind-gut turned red on exposure to air. The oxidation was accelerated in the presence of ammonia fumes. The dried contents of the hind-gut gave a blue color with concentrated sulfuric acid and with alkali. The Malpighian tubules and the haemolymph gave negative tests for phenothiazone and thionol.

A total of 50 insects were dissected to determine the contact action of phenothiazone. The compound applied to the cuticle was toxic and was converted to the leucothionol conjugate in the haemolymph in the manner reported for phenothiazine. The conjugate reached a concentration in the haemolymph sufficient to form a deep red or blue color with sulfuric acid before the insect succumbed. The Malpighian tubules of the dead insect contained the red oxidized form of the thionol conjugate.

The insect recovered if the amount of phenothiazone in contact with the cuticle was insufficient to produce a lethal concentration of the leucothionol conjugate in the haemolymph. In such cases the Malpighian tubules usually contained the reduced form of the conjugate.

The contents of the hind-gut of the insects treated with phenothiazone responded to the tests for a leucothionol compound. The fore-gut and the mid-gut gave negative tests with sulfuric acid.

No attempt was made to determine the effect of the particle size on the toxic action of phenothiazone.

Phenothiazone was injected into 35 insects. A suspension in water injected into the haemocele killed the insects if the concentration of the leucothionol conjugate in the haemolymph was large enough to produce a deep red or blue color with concentrated sulfuric acid. The insects showed an uncoordinated walk and recovered, or were visibly unaffected if a sub-lethal amount was introduced. The observations of the Malpighian tubules and of the alimentary canal were similar to those recorded for insects injected with phenothiazine.

EFFECT OF THIONOL.—Thionol and its sodium salt were not toxic in the alimentary canal of the 75 insects used in the experiment. No change in the compounds was observed in the crop. The contents of the hind-gut were gray in color, turning red on exposure to air, and they gave the color reactions for leucothionol by forming a blue color with sulfuric acid and with alkali. The Malpighian tubules and the haemolymph gave negative tests for thionol.

Neither thionol nor its sodium salt in contact with the cuticle produced a toxic effect upon the insect. The haemolymph and the Malpighian tubules of the 140 insects dissected gave negative tests with sulfuric acid, alkali and oxidizing agents. The hind-gut contained a gray fluid which responded to the color reactions for leu-

cothionol with sulfuric acid and with alkali. The fore-gut and the mid-gut gave negative tests for thionol.

A water suspension of thionol and a solution of the sodium salt were injected into the haemocele of 70 insects. The insects were not visibly affected by the injections although enough of the salt was introduced to impart a blue color to the abdominal contents.

In roaches dissected from 12 hours to 7 days after treatment, the haemolymph gave negative tests with sulfuric acid and with alkali. Particles of thionol were found enmeshed in the alary muscles and among the fat bodies of the insects treated with both thionol and the sodium salt. The Malpighian tubules contained amorphous black particles if a large amount of thionol was injected. These particles responded to the color tests for thionol. The Malpighian tubules usually contained thionol in solution as detected by the homogeneous blue color with sulfuric acid.

The hind-gut contained a gray fluid which responded to the tests for leucothionol. The fore-gut and mid-gut gave negative tests for thionol.

DISCUSSION.—Phenothiazine kills the American cockroach, *Periplaneta americana* (L.), by producing a definite concentration of a leucothionol conjugate in the haemolymph. The lethal concentration is produced by the slow formation of the conjugate converted from the phenothiazine in contact with the cuticle; and it is reduced by active elimination through the Malpighian tubules. The conversion of phenothiazine might take place during its passage through the integument since the haemolymph gives a negative test for phenothiazine.

The speed with which the lethal concentration of the leucothionol conjugate in the haemolymph is reached depends upon the surface dosage and upon the particle size of the phenothiazine. Particles of the smallest size are in intimate contact with the cuticle, and the concentration of the conjugate increases beyond the eliminating capacity of the Malpighian tubules. This conclusion is affirmed by the observation that a sub-lethal concentration of phenothiazine either introduced into the haemocele or in contact with the cuticle produced uncoordinated walking movements with subsequent recovery as the Malpighian tubules decreased the concentration of the leucothionol conjugate in the haemolymph. The effectiveness of the fine particles might be due to an increased solubility of the phenothiazine either in the external secretions of the dermal glands or in the epicuticle itself (Wigglesworth 1939).

The large particles usually do not kill the insect in spite of a large surface dosage since the Malpighian tubules are capable of maintaining a sub-lethal concentration of the leucothionol conjugate in the haemolymph. These observations agree with the report of Siegler & Goodhue (1939) that phenothiazine particles averaging 4 and 15 microns in diameter were effective against codling moth larvae, whereas particles with an average diameter of 45 microns were much less effective in spite of an increase in dosage. The action of phenothiazine observed in the American cockroach may be similar to that in other insects, since Deonier & Lindquist (1942) observed that the larvae of the Clear Lake gnat could recover from the effects of phenothiazine. These investigators also recorded the presence of a dark brown compound in the Malpighian tubules, which was perhaps similar to the thionol conjugate observed in this investigation.

The variation in kill between the dust and the spray reported by Batchelder *et al.* (1937) and by Wilcox & Stone (1940) may be due to a similar contact effect. During the course of this investigation it was observed that superior results were obtained if phenothiazine was wetted before being applied to the cuticle. Under these conditions the particles adhered to the cuticle as the water evaporated.

The variable toxicity reported for codling moth larvae (Bourne 1938, Webster *et al.* 1940) and for mosquito larvae by King (1938) finds a possible explanation in differences in particle size in addition to the eliminating effect by the Malpighian tubules if the results with the American cockroach prove applicable.

A more rapid kill of *Periplaneta americana* (L.) is believed possible by allowing the insects to remain in phenothiazine vapor. This phase of the problem was not examined at great length since the insect was usually killed at the temperature necessary to vaporize phenothiazine. Two insects of a series died within an hour after exposure to phenothiazine vapor,

showing the internal distribution of the leucothionol conjugate typical of an insect killed by the contact effect of phenothiazine crystals. The rapid kill probably results from the phenothiazine entering the haemolymph by way of the tracheal system. This phase of the problem should be further investigated, preferably with a heat resistant insect such as *Thermobia domestica* (Packard) which is not affected by phenothiazine mixed with food according to Snipes *et al.* (1936).

The toxicity of phenothiazine against the American cockroach might be due to the inhibition of the respiratory enzyme, cytochrome oxidase, by the leucothionol conjugate in the haemolymph. Keilin (1929) found that cytochrome oxidase was generally present in insects. Positive tests were obtained with alkali and with Folin-Ciocalteu reagent for the presence of free phenolic groups in the leucothionol conjugate. Collier (1940a, 1940b) and Collier & Allen (1942b) found that the hydroxy derivatives of phenothiazine inhibited this respiratory enzyme. These investigators also found that the degree of inhibition varied with the concentration of the derivative. This observation might be correlated with the uncoordinated movements of the insect at a sub-lethal concentration of the leucothionol conjugate in the haemolymph.

The elimination of the thionol conjugate in the haemolymph takes place exclusively through the Malpighian tubules. This observation is in agreement with the statement by Wigglesworth (1939) that the alimentary canal of insects does not have an excretory function. The conjugate was present throughout the lumen of the Malpighian tubules of the cockroach, whereas Deonier & Lindquist (1942) found in the larvae of the Clear Lake gnat that a red compound resulting from phenothiazine was present only in the proximal portion.

Phenothiazine is not toxic in the alimentary canal since the wall of the canal is impermeable to the compound. The crop acts as a storage organ, usually producing no change in the compound except in a few cases where a blue-green compound was formed, reported to be isomeric with phenothiazine by Smith (1938). It is of interest to note that the conversion of phenothiazine takes place in the mid-gut, which is the only portion of the alimentary canal producing digestive enzymes according to Abbott (1926). Woke (1940) reported that no cellular changes occurred in the mid-gut of the southern army-worm killed by phenothiazine. He apparently considered that the compound functioned as a stomach insecticide.

The mid-gut appears to have the ability to convert a specific quantity of phenothiazine to a compound responding to the color tests for leucothionol. No phenothiazine was detected in the mid-gut, and it was found only occasionally in the hind-gut during normal feeding upon a low concentration of phenothiazine. However, after ingestion of the undiluted compound only a portion of the phenothiazine was converted in the mid-gut, and the free crystals were detected both in the mid-gut and in the hind-gut.

The influence of the different foods and salts upon the action of phenothiazine in the alimentary canal was investigated because DeEds & Thomas (1941) have suggested that the insecticidal action of phenothiazine might result from the permanent oxidation of the respiratory enzyme system by the leucothionol-thionol system. The variation of the oxidation-reduction potential with pH is well known through the work of Clark *et al.* (1928). Wigglesworth (1927) observed that the pH in the alimentary canal of the cockroach varied with the food ingested. He found that sucrose, starch, glucose and gelatin produced pH values from 4.5 to 6.4 in the crop. Bowe (1927) reported that the addition of neutral salts affected the pH. The use of the different foods and salts however did not affect the action of phenothiazine in the alimentary canal of *Periplaneta americana* (L.).

No correlation was observed between the toxicity of phenothiazine to insects as recorded in the literature and the pH values of the haemolymph and alimentary canal as compiled by Staudenmayer (1940). His compilation included data for thirteen insects which had been treated with phenothiazine by different investigators.

Phenothiazone, the oxidation product of phenothiazine, contains a carbonyl group in the molecule. This compound is similar to phenothiazine in its effect upon the American cockroach. Thionol has no toxic effect in the alimentary canal or in contact with the cuticle. The addition of

a hydroxyl group to the phenothiazone radical apparently renders the compound nontoxic to the cockroach. No satisfactory explanation for this lack of toxicity is offered.

SUMMARY.—1. Phenothiazine, phenothiazone and thionol were tested for their toxic effect on, and internal distribution in the American cockroach, *Periplaneta americana* (L.).

2. Phenothiazine, phenothiazone and thionol are not toxic in the alimentary canal. The lack of toxicity of phenothiazine and phenothiazone is due to the impermeability of the intestinal wall to these compounds. Phenothiazine, phenothiazone and thionol are converted to a compound which gives the reactions for leucothionol during passage through the midgut.

3. Phenothiazine and phenothiazone are toxic in contact with the cuticle and when injected into the haemocele. Thionol is not toxic under the same conditions.

4. The toxic action of phenothiazine and phenothiazone is produced by a leucothionol conjugate formed from the compounds. The conjugate must reach a definite concentration in the haemolymph before the insect succumbs. A sub-lethal concentration produces an uncoordinated walk and the insect recovers as the conjugate is eliminated through the Malpighian tubules.

5. Phenothiazine particles of the smallest size kill the insect in the shortest time with the least quantity in contact with the cuticle.

6. The toxic action of phenothiazine and phenothiazone may be due to the inhibition of the respiratory enzyme, cytochrome oxidase.—9-7-44.

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FREE TRADE IN NURSERY STOCK BETWEEN ARKANSAS AND OKLAHOMA

Under an agreement just reached between the Oklahoma State Board of Agriculture and the Arkansas State Plant Board, nursery stock can hereafter be moved between the states of Arkansas and Oklahoma without any restrictions except that each shipment must bear the inspection certificate of the state of origin.

The agreement provides that equivalent methods of nursery inspection shall be used in each state, and sets up other safeguards to protect the interests of each state. Arkansas will no longer require Oklahoma nurseries to file copies of their inspection certificates and secure permits for shipments going into Arkansas, and Oklahoma will extend similar privileges to Arkansas nurserymen.

The agreement does not apply, however, to the licensing of agents, or of nurserymen or dealers who go into the other state to solicit orders for nursery stock.

A similar agreement has been in effect between Arkansas and Missouri since 1938.

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Changes in California Red Scale Populations Following Sprays of Oils With and Without Derris Resins

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Several investigators have shown that the addition of cube or derris resins in a suitable solvent to oil sprays increased the kill of the California red scale, *Aonidiella aurantii* (Mask.), but there has been little quantitative information on the subsequent infestations (Ebeling 1940, Cressman 1943b, McBeth & Allison 1941). Cressman (1943a) also has found that a greater increment of kill resulted from the addition of derris resins to light medium oil than to heavy oil but called attention to the importance of a possible difference in the residual action of the two oils against the crawlers. Scale populations 6 months or a year after treatment may not be directly proportional to the numbers of scales surviving the sprays, because of differences in the residual action of different oils or a more rapid increase in infestation in the plots with fewer survivors. In order to obtain more definite information on this subject, data were obtained by the Whittier, Calif., laboratory on scale-population changes following the application of sprays of extra light to heavy oils alone and the same oils with added derris or cube resins. The important data are the basis of this report.

Spray Materials and Applications.—An oil containing a glyceryl oleate emulsifier was used in all sprays. The light medium to heavy oils met the specifications of the California Department of Agriculture, as published by Cox (1938). Specifications of the extra light oil were as given by Cressman & Broadbent (1943). The rotenone content of the cube or derris resins ranged from 20 to 33 per cent, and the red color-value by the Goodhue test, which is probably a better index of toxicity to the red scale, ranged from 36 to 57 (pure rotenone = 100). In most groves the resins were added to the oil to make mixtures containing 1.1 to 1.2 per cent by weight of resins. In some tests the derris resins were first dissolved in a mixture of 2 volumes of dibutyl phthalate and 1 volume of trichloroethylene at the rate of 15 grams of resins per 100 cc., while other prays used a solution of resins in dibutyl phthalate at the rate of 10 grams per 100 ml. The two solvents were equally effective in field sprays.

With two exceptions, the applications were made by commercial operators with their regular spray crews, using spray tanks of 300- to 500-gallon capacity, and oil concentrations from 1.67 to 2 per cent. Spray applications varied considerably in uniformity and amount of material per tree, and are probably typical of the range of variation that would be encountered under conditions of commercial application. Plots were randomized in solid plots of trees. In these commercial-scale tests the plots contained at least 20 trees, of which 10 to 12 were used for population counts and 8 to 10 others for natural and spray mortality.

In groves F and H sprays were applied with a small power sprayer with a 100-gallon tank, and each plot consisted of 5 trees. In these smaller plots it was necessary to make the mortality counts on the same trees used for population studies. Although some of the living scales were destroyed in order to determine the percentage dead, the heavy infestation in these plots made it unlikely that this procedure appreciably affected the results.

Estimating Populations and Mortality.—It was found most practicable to limit the counts to adult female scales in which the width of the annular ring of new wax equalled or exceeded the radius of the exuvia. The majority of such scales were mature, and many were reproducing. When younger stages were included, reproducible results could not be obtained, probably because of the difficulty of seeing the smaller scales with the unaided eye.

With the exception of a few supplementary observations on the fruit, the population and mortality counts were made on wood. Although populations on the wood are more difficult to estimate than those on leaves or fruit, the continuity of record which can be obtained and the fact that a large part of the live scales in oil-sprayed groves are found on the wood were important reasons for deciding

to follow population density on this part of the tree. No counts were made on leaves because they bear a relatively small proportion of the total scale population. Infestation on the fruits depends partly on their age, and they are picked a number of times each year, at which times the oldest and most heavily infested lemons are removed. The effect of the scale infestation on the grading of the fruit is of economic importance, and therefore occasional estimates of fruit infestation were made.

At first, field counts were made only on the younger or green wood. These were supplemented by microscopic examination of the older branches, or gray wood. Later it was found that counts of the total population on the gray wood could be made about as rapidly and as accurately as those on the green wood, although some magnification such as was obtained with binocular loupes was necessary to obtain reproducible estimates of mortality. Twig units examined were either 3 or 6 inches long, depending on the density of infestation. Most of the gray wood examined was about 1 to 1.5 centimeters in diameter, a type of wood that is liable to heavy infestation. In the case of the gray wood, only the scales on the upper half of the branch were counted. All sizes of green wood, except the flush growth, were included, and the entire area of each unit was examined.

A definite number of units were examined from each quadrant or octant of the tree, at heights approximately between knee and eye level. Green-wood units were selected equally from the outside and inside of the tree, but this was not practicable for gray-wood units, samples of which were randomly collected in this respect. The pattern of scale distribution with respect to direction, height, and inside or outside position was always consistent within a single count on an experimental block, but showed considerable variation in groves in different localities or in counts made at different seasons. The size of the samples varied according to the density of infestation, and was sufficient to yield more than 20 scales on most trees. Both living and dead scales on gray wood were included in the population counts, and a separate estimate of mortality was then made. In the earlier experiments mortality was determined by microscopic examination, but in later work field counts using binocular loupes were the standard method. At first, counts on green wood were made like the gray-wood counts, but later it was found practicable to distinguish and count only live scales in the field.

Since measurements of population growth involve at least two estimates of the population, at the beginning and at the end of a period, both of which are subject to error, the accuracy of estimate is a matter of considerable importance. It was found that the relative variances were about the same whether 3- or 6-inch units were taken, but that there was a tendency for the relative variability to decrease slowly as population density increased. For example, in one count the coefficient of variation ranged from about 140 to 70 per cent as the density increased from 1 to 13 scales per unit. Larger samples were taken in the less heavily infested groves to compensate for this tendency. In general, the relative error of estimate of the plot mean for either green or gray wood has ranged from about 7 to 12 per cent. When green- and gray-wood counts were combined for a single estimate, as was done where both types of estimate were available, this error of course was less.

Total initial population and natural mortality were estimated before spraying. In some of the first test plots, estimates of population and mortality were attempted at close intervals, but it was found that little information was gained by such counts, and the general practice was to make only initial and final estimates.

Spray mortality was regularly determined about 6 weeks after the application, the counts being limited to the same stages used in population counts. The younger stages are nearly wiped out by reasonably thorough commercial spraying. For example, in one test, in which younger stages were examined, 64 per cent of the late gray and older stages survived, but only 0.3 per cent of the second molt and early gray adult stages on the gray wood survived. Therefore most of the survivors of the sprays were included in the stages counted.

The final population estimates were made just before the next spray application, the interval between the two counts, with one exception, ranging from about 6 months to a year. Since there is little increase in the adult scale population during the winter months, those experiments in which sprays were applied in the spring

and in which final counts were made in the late fall covered the part of the year during which most of the population increase occurred.

EXPERIMENTS WITH LIGHT MEDIUM TO HEAVY OILS PLUS DERRIS RESINS.—In August 1940 a 4-acre grove was divided into three plots, two of which were sprayed with 1.67 per cent of heavy oil and one with the same oil plus 1.1 per cent of derris resins. Counts on fruit were made in December, and on green wood the following May. Infestations on fruit in the oil and the oil-plus-derris plots were 4.1 and 1.7 scales per lemon, and on the green wood 3.3 and 1.3 scales per unit.

Commercial-scale tests from 1941 to 1943 were made with 1⅔ to 2 per cent of light medium and heavy medium oils in five lemon groves in the vicinity of Whittier, Corona, and San Fernando. Two tanks of each oil alone and two with added derris resins were applied in each grove. Data on the spray applications, oil deposits, and mortality and population counts are summarized in table 1.

In the case of grove D, sprayed March 30, 1943, the owner subsequently decided to offer it for sale and resprayed the whole grove in July. It was necessary, therefore, to make the final counts July 19 to 21. At that time mortality on the gray wood was too high (88 to 96 per cent) to permit an accurate count of the live scales, and population estimates were limited to green wood and fruit. The initial populations, i.e., those present before spray applications, and both initial and final populations in the other groves are averages of the living scales on gray and green wood.

There were no consistent differences in the quantities of oil deposited by the four materials. Mortalities were increased considerably by the addition of the derris resins. There was little difference in oil deposits in groves C, D, and E, but the mortality in grove C was, for some unknown reason, much higher than in the other two. Such differences have occurred with other sprays, but tests on scales collected from different sources and reared in the laboratory have not shown any large differences in inherent susceptibility to oils.

The average final population in the plots treated with oil alone was 2.3 times that in plots treated with the oil plus derris resins. These differences were shown to be highly significant by an analysis of the covariance between the final and initial populations. (In the analysis the numbers of scales per unit were first converted into logarithms because the standard deviations tended to be proportional to the mean.) There were no significant differences between the populations in the plots treated with light and heavy medium oil, whether or not derris resins were added.

Final counts on the fruit in groves D and E gave results closely parallel to those obtained on the wood. No fruit counts were made in the other groves.

In two experiments (Groves F and G), where sprays were applied in September and October, 1940, there was little or no difference in the populations 11 months later in spite of large differences in the numbers surviving the sprays. Grove F was treated with 1.0, 1.5, and 2.0 per cent of medium oil alone and with cube resins. Mortalities ranged from 22 per cent with 1.0 per cent of oil alone to 93 per cent with 2.0 per cent of oil plus 1.5 per cent of cube resins. Grove G was treated with 1.7 per cent of light medium and heavy medium oil alone and with added cube resins. The

Table 1.—Materials applied, oil deposits, and mortality and population counts in experiments with light medium and heavy medium oil with derris resins. Each figure is an average of two plots.

Material	Oil Deposit[1]	Mortality Per Cent	Population 3-Inch Unit[2]	
			Initial	Final
Grove A, sprayed Sept. 10, 1941, final count Sept. 1942				
Light medium oil	—	53.9	0.68	0.89
Light medium oil+derris resins	—	85.0	0.76	0.82
Heavy medium oil	—	27.2	0.68	0.86
Heavy medium oil+derris resins	—	78.1	0.77	0.82
Grove B, sprayed May 5, 1942, final count December, 1942				
Light medium oil	157	91.5	3.08	5.33
Light medium oil+derris resins	159	97.9	2.34	2.54
Heavy medium oil	176	89.4	2.05	5.30
Heavy medium oil+derris resins	151	98.6	2.41	1.52
Grove C, sprayed June 11, 1942, final count December, 1942				
Light medium oil	107	92.4	2.01	1.46
Light medium oil+derris resins	100	97.6	2.10	0.86
Heavy medium oil	120	94.7	2.48	1.37
Heavy medium oil+derris resins	104	97.0	1.66	0.74
Grove D, sprayed March 30, 1943, final count July, 1943				
Light medium oil	106	65.6	7.42	0.79
Light medium oil+derris resins	110	91.0	8.44	0.50
Heavy medium oil	114	67.4	6.59	0.76
Heavy medium oil+derris resins	112	90.8	7.70	0.39
Grove E, sprayed June 21, 1943, final count December, 1943				
Light medium oil	100	51.4	0.78	1.82
Light medium oil+derris resins	112	93.6	0.67	0.61
Heavy medium oil	110	75.9	1.17	2.22
Heavy medium oil+derris resins	112	93.0	0.78	0.42

[1] Micro-milliliters per square centimeter.
[2] Before spraying.

average mortality from oil alone was 50 per cent, and from oil plus cube resins 88 per cent. Conditions during 1941 were relatively unfavorable for the red scale. Mortality remained high through the spring and summer and was 62.4 per cent in Grove F in August and 67.5 per cent in Grove G in September when final counts were made. The final populations in Grove F were only 18 per cent of the populations before spraying; in Grove G, 26 per cent.

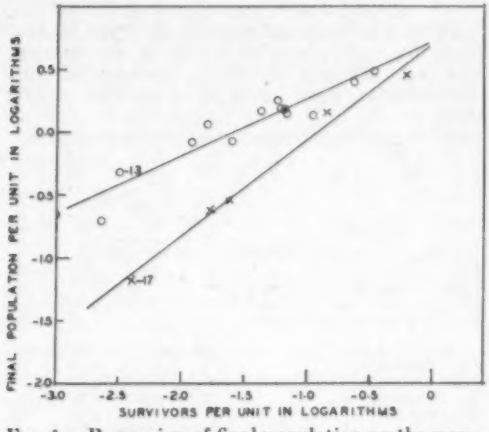

FIG. 1.—Regression of final population on the number of scales surviving sprays of extra light oil, shown by circles, and of light medium oil, shown by crosses.

They tended to reach a uniform level that was largely independent of treatment.

EXTRA LIGHT AND LIGHT MEDIUM OILS.—Sprays of light medium oil plus 1.1 per cent of derris resins, and of extra light oil alone and with 0.33 and 0.67 per cent of derris resins, were applied in grove H between September 24 and October 13, 1942. Two solvents, *Cardolite*[1] and a mixture of dibutyl phthalate and trichloroethylene were used, and oil concentrations were varied in an effort to get equal deposits from different combinations in the later sprays. The concentrations ranged from 1.75 to 2.0 per cent of light medium and from 2.0 to 3.0 per cent of extra light oil.

Because of the number of solvents and oil concentrations used the experiments as a whole do not permit a precise estimation of the effect of the addition of derris resins, but with a range of spray survivals of from 0.1 to 18.5 per cent, the relative rates of increase in scale population following the use of these sprays provide a good measure of the residual effects of these two types of oil. The number of scales surviving the sprays was estimated from the initial population counts and the percentage of survival. When the logarithms of the final populations were plotted against the logarithms of the survivors the results could be fitted by a straight line as shown in figure 1. The differences in the residual action of the two oils can be measured by the differences in the position of the two regression lines at each level of spray survival. The light medium oil retarded the rate of reinfestation more than did the extra light oil, and the relative differences in the final populations were greater in the region of higher kills. Thus the number of scales surviving the spray in plot 13, treated with extra light oil, was slightly less than in plot 17, treated with light medium oil, but in August 1943 plot 13 had 7 times the infestation of plot 17.

The extra light oil was also less effective against the citrus red mite. Samples taken in June 1943 showed about five times as many mites on the trees sprayed with extra light oil as on those treated with light medium oil. The data obtained with the light medium oil and the heavy medium oil, discussed earlier, were not sufficient to justify a comparison of the effectiveness of these oils in controlling red mites.

DISCUSSION.—Cressman (1943a) has reported experiments in which a heavy oil killed more scales than a light medium oil, but the differences were small, and it is not surprising that no differences in the mortalities from heavy medium and light medium oil could be detected under the more variable conditions of commercial application. It was anticipated, however, that the light medium oil would have less residual action against the crawlers and would permit a faster buildup in infestation after spraying than would the heavy medium oil. This was not the case in the experiments listed in table 1. Other methods of analysis were used including the use of the actual populations instead of their logarithms, and the ratios of the final to the initial populations, analyzing the five groves separately and in combination. No method demonstrated any superiority of the heavy medium oil. However, the differences between the residual effects of the light medium and extra light oil were clearcut.

[1] A formaldehyde reaction product of cashew nut-shell liquid.

A study of the data from the two series of experiments has shown that the relative rate of increase was greater with the lower initial populations, and differences among the final populations were less than the differences in the numbers of scales surviving the sprays. The fact that the relative rate of growth tends to decrease as the population increases, at least within certain limits, has been found to be a general characteristic of animal populations. Its occurrence in these studies emphasizes the practical point that within the range of populations encountered in these experiments a more intensive treatment is required to maintain a consistently low infestation than to maintain a higher one.

During the summer of 1941 a considerable acreage of citrus in southern California was treated with commercial oils containing rotenone. As a result of a survey of about 250 groves the following winter, Woglum (1942) reported that no benefits from the use of rotenone were evident. The exact dosage used in these orchards is not known, but much of the oil contained only 0.05 per cent of rotenone and very little contained more than 0.12 per cent, with varying amounts of the other extractives. Results published by Cressman & Broadbent (1943) as well as unpublished data show that the minimum concentration of rotenone in oil required to increase the kill is about 0.10 per cent of rotenone plus the other extractives of derris root commonly found in the resins. If the other extractives are absent, a greater concentration of rotenone would be required. It is probable, therefore, that the low rotenone and extractive concentrations were a factor in the failure to improve results in the sprays discussed by Woglum. Ebeling *et al.* (1944) have since reported experiments in which a reduction in the number of infested fruits resulted from the addition of derris resins and powder.

The results presented in this paper show that populations after spraying were generally reduced by sprays containing 1.1 per cent of derris or cube resins (about 0.3 per cent rotenone) in oil. In the cases where little or no reduction in the populations about a year after spraying resulted, the conditions were relatively unfavorable for the red scale and final infestations were low. Benefits from the use of derris resins are most likely to be obtained when conditions favor red scale increase, the time that they are most needed.

SUMMARY.—Populations of the California red scale on lemon trees were measured just before and again about 6 to 12 months after they had been sprayed with extra light to heavy oils both alone and with added derris resins.

The scale populations were measured on the wood with a few counts on fruit.

In five groves treated with light medium and heavy medium oils, final infestation on the wood was about 2.3 times as heavy in the plots treated with oil alone as in those where derris resins were added. Infestation on the fruit was also heavier when no derris was used.

There was no difference in either the immediate or the residual effectiveness of the light medium and heavy medium oils whether or not derris resins were added, but a light medium oil showed more residual action than an extra light oil.

In general, the relative rate of population increase was greater the smaller the number of insects surviving the sprays, and differences in the final populations were less than the differences in survival.

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Some Ecological Relationships of *Cnephasia longana*[1]

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The key to the solution of the manner of field distribution of the omnivorous leaf tier, *Cnephasia longana* Haw., was the discovery in 1940 that the eggs were laid on the trunks of rough barked trees (Rosenstiel 1941). Previous observations by use of flypaper in 1938 indicated the probability that the wind was involved in the spread of the insect. Subsequent observations revealed the role of the wind in distributing the first instar larvae and the reasons for some cases of apparent host immunity. The cultural and other ecological relations of this lepidopterous pest have been intensively studied in the attempt to find either a cultural control or a point in its life history that would be vulnerable to chemicals.

Oviposition.—In 1940 female moths were observed as they oviposited on an unpainted shingled shed, on bark of apple, ash, prune, oak and cherry trees, on weathered cedar fence posts and to a slight extent on a painted building where the paint had cracked. Oviposition began half an hour after sundown provided the wind was not blowing. When the wind blew noticeably in the evening the moths sought shelter by clinging to plants near the ground. The peak of egg laying was near 8:30 p.m. and terminated about midnight as the temperature decreased. Most of the eggs were deposited in the range of 2 to 20 feet above the ground although some egg laying was observed in tree tops 40 feet high.

The female moths flew to tall objects when they were ready to oviposit and dragged the sensitive lip of the ovipositor over the surface of the support. They moved apparently at random until the ovipositor came in contact with a crevice. The tip of the abdomen was then used for further exploration of the crevice and if it was found suitable the glistening egg was laid either in the crevice or on its edge. After oviposition the abdomen was brushed sideways several times over the sticky egg which caused the adhesion to it of adjacent loose bark particles and a few scales from the abdomen of the moth. The eggs are orange-colored when laid but are effectively camouflaged by the brushing of the female as each one is deposited.

In 1942 tests were made in a field insectary in the effort to learn the type of bark surface chosen by the females for oviposition. One and a half inch cubic blocks bearing bark on one surface were cut from sixteen different species of trees. Two other kinds of blocks made from lumber were also tested together with part of a weathered cedar fence post. Three plywood sheets each bearing six replicated blocks of each kind arranged at random were exposed in outdoor cages to ovipositing omnivorous leaf-tier moths. During the winter the blocks were stored in quarter-pint cartons in an outdoor insectary. After normal field emergence had been completed the blocks were examined to determine the number of empty egg shells and larvae on the various kinds of surfaces.

Table 1 shows that rough-barked trees

Table 1.—The number of *Cnephasia* larvae hatching from various wooden cubes.

Kind of Wood	Average S[1]	Average L	High S	Low S
A. Douglas fir—*P. taxifolia*	107	25	+	
B. Oak—*Q. garryana*	50	8		
C. White fir—*A. grandis*	182	21	+	
D. Ash—*Fraxinus oreganus*	9	0		
E. Maple—*A. macrophyllum*	126	10	+	
F. Willow—*Salix* sp.	30	5		−
G. Vine maple—*A. circinatum*	56	5		
H. Cedar—*Thuja plicata*	36	9		
I. Cottonwood—*P. trichocarpa*	4	1		−
J. Madrone—*A. Menziesii*	39	4		
K. Cottonwood—old	82	7		
L. Cherry—cultivated	3	0		
M. Prune—cultivated	168	7	+	
N. Apple—cultivated	33	2		−
O. Peach—cultivated	155	14	+	
P. English Walnut—*J. regia*	5	0		−
Q. Black walnut—*J. nigra*	157	21	+	
R. Rough lumber—Douglas fir new	1	1		−
S. Nailed lath cubes—fir	0	0		−
T. Cedar fence—post old	157	10	+	
U. Chittim—*R. Purshana*	205	12	+	

[1] "S" refers to empty egg shells while "L" refers to *Cnephasia* larvae.

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such as white fir, prune, and black walnut were favored for oviposition. The eight highest and lowest counts are marked with a "+" and a "−" respectively. The abundant oviposition on smooth-barked chittim is not explained by this test.

WIND DISPERSAL.—The larvae which emerge from hibernation in the early spring are carried from their winter quarters by the force of the wind exerted on their bodies and on the silken strand which they extrude as they are carried away. When a larva is ready to leave its winter quarters it first fastens a strand of silk to the rough surface on which it is crawling. Its next move is to jerk its head and thorax sharply backward and then to push away from the trunk with the posterior end of its abdomen. This maneuver causes the larva to spring about half an inch away from the surface of its resting place. Sometimes the wind would catch them as they left the surface and bear them away with their silken strand. The tiny larvae spun out about five inches of silk before the wind whipped them through the air enough to break the strand. The thread of silk always broke at the tree end and served the purpose of increasing the body surface that was exposed to the wind. When the wind velocity was insufficient to bear the larvae away from the bark they simply swung back to their base and later tried the performance again.

The direction and distance that the larvae were borne by the wind was important in working out cultural control measures. The "flight" of the larvae through the air could only be followed by the eye for about a yard due to their small size. The extent and direction of ballooning was determined by plotting larval injury in fields near hibernating quarters. Yard-square wire quadrats were used in this study and two quadrat samples of webbed tips of flax or vetch were examined at each station. The total number of webbed tips of these two samples was recorded for each station on charts of the fields. The stations were generally ten yards apart although they were sometimes twenty or forty yards apart in strawberry fields, where 100 berry samples were examined for injury at each station. Larval injury was most easily seen on young flax plants so most of the information was first obtained from their study and later verified on other crops. Flax fields were sampled for larval leaf-tier injury before 1941 in six spots. Samples were taken from the sides of the field by walking along and pulling a small handful of flax at random every few paces. Two similar samples were taken from the center of fields by pulling samples along a north to south and east to west line. These samples were labeled and taken to the laboratory where 200 stalks were picked at random from each sample and counted for injury (Table 2).

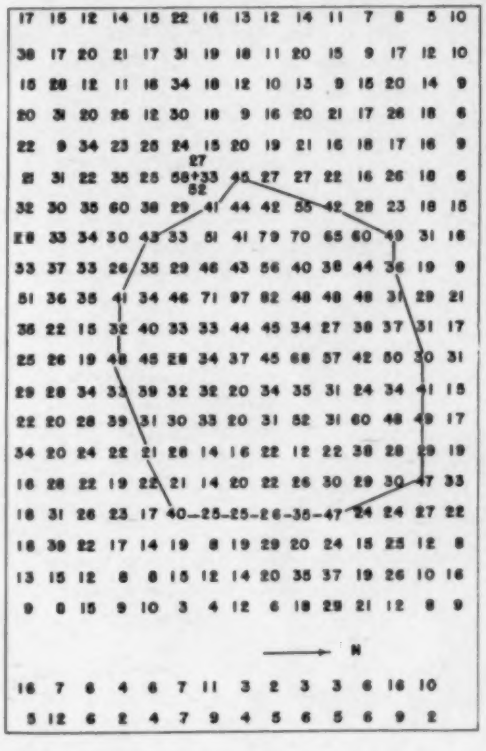

FIG. 1.—Flax injury around an oak tree.

Lines on figure 1 connect stations where injury counts ranged from 40 to 49 around the "+" on the chart which indicates an oak tree 60 feet high. There were no other trees or tall objects near the field from which the larvae could have been carried. Study of the chart shows the basic eastward "drift" tendency of the larvae which was also found in studies of many other fields. During 1941 and 1942 a total of 51 fields were examined systematically for larval injury and the results charted and studied. The following statements may be made based on results of these field studies in the Willamette Valley.

1. There is a larval "drift" of first instar *Cnephasia longana* during the early spring from the SW, W, or NW. The drift distance varies with the height at which the larvae leave their support and the wind velocity.
2. Barriers such as buildings or brush hedges deflect wind currents upward and in that way the larvae are carried farther past the barrier than would otherwise occur.
3. Douglas fir and oak trees are the most important sources of drifting larvae because their height makes possible a high elevation for initial larval drifting and their numerous bark crevices furnish a refuge for overwintering larvae. These are the most abundant "wood lot" trees in the Willamette Valley. Rough or shingled unpainted buildings may be the source of a number of larvae at locations where trees are scarce.
4. Where the overwintering population is concentrated there may be many larvae that drop to the ground within a five to ten yard radius of such low trees as filberts or small fruit trees. The only definite western drift observed was under such conditions.
5. Drifting from fence posts and telephone poles also occurs in an easterly direction but is relatively unimportant probably due to the small number of larvae overwintering on them.
6. Larvae falling on clean cultivated ground will soon starve to death. They may travel a few inches in search of food if necessary.

CROP INJURY.—After the larvae were carried away from their winter resting place they traveled downwards. If caught on tree twigs, fences, tall thrubs or even tall grass they were observed to immediately descend to lower plants beneath them. This activity protects fruit and nut trees and cane fruits from thier depredations at this leaf-mining stage. After the larvae had found a suitable non-grass host they proceeded to mine in the leaves until the third instar. Soon they left their mine and after some preliminary movements climbed upwards to the tender growing tip of their host. After finding suitable tender food they webbed surrounding plant parts together to make a shelter nearly impervious to insecticides and predators. When larvae were removed from their webbed feeding place and put on the base of another plant they continued to exhibit preference for the upper parts of the host. Study of this habit revealed that several flax tips or vetch blossoms were injured by each larva during the feeding season. The wind was an agent in this activity because it blew the plant tips close together so that the larvae were able to stretch out, catch a waving plant tip and climb over to the new host.

The first instar larvae do not mine in grass leaves so grain crops and grasses are generally free from damage. Exceptions have been observed in the case of wheat and corn adjacent to or mixed with some vetch. The larvae fed on the vetch during their early stages and then moved to the tender wheat heads at the time the kernels were forming and did considerable injury. Seedling corn adjacent to vetch has been damaged.

The larvae usually emerge from hibernation during March so late-planted crops such as corn or potatoes escape injury provided the ground was clean-cultivated at some time before the crop appeared above the ground. A few weeds that survived cultivation were sometimes the source of a small number of larvae which damaged late-planted crops.

A few cases of injury to filberts have been known where a legume cover crop was plowed up in the early summer. In these cases the *Cnephasia* larvae were feeding on the legume and when it was plowed under they ascended and fed on the tree foliage.

Legumes are the principal hosts of *Cnephasia* larvae. The common legumes such as vetches, clovers, and alfalfa are present during the winter and in the early spring furnish a convenient host for leaftier larvae. The foliage of the legumes is abundant and the larvae can easily move over a plant as they feed on a succession of flower buds and tender leaves.

CROP PRECEDENCE EFFECTS.—Beginning in 1941 2-square-yard samples were examined in the spring in the field at 10- or 20-yard intervals in a checker-board pattern over the whole of each field. The injury recorded for each point on the charts was the sum of the injured flax tips in the 2-square-yard sample. These samples were related to those made before 1941 by counting the flax stalks within a

yard square on several fields and transposing post 1941 results to percent injury.

Table 2.—Six-year summary of the preceding crop relation to flax damage done by the omnivorous leaf-tier.

PRECEDING CROP	No. FIELDS SAMPLED	AVE. PER CENT INJURY ON FLAX
1. Legume	90	11.7
2. Cultivated crop	36	3.3
3. Grain	27	3.2
4. Flax	13	3.5
5. New Ground[1]	8	1.6
6. Early-sown and over-wintering crops[1]	104	7.6
7. Grain and late-planted crops[1]	63	2.7

[1] Group 5 was usually a mixture of grass and weeds. Legumes were included in group 6, while group 7 was made up of cultivated crops and grain.

Figure 2 shows legumes to be far the most important crops preceding flax in building up *Cnephasia* populations. The cultivated crops were nearly always either corn or potatoes which were of course planted in the late spring after the *Cnephasia* larvae had all left their winter quarters.

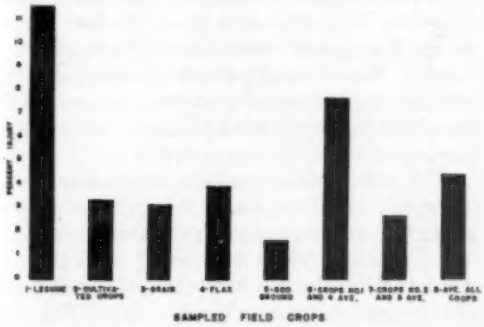

FIG. 2.—A six-year average of *Cnephasia* injury on flax preceded by various crops.

SUMMARY.—The life history, feeding habits, and ecological relations of *Cnephasia longana* have been studied for the purpose of finding a means of control. These studies may be summarized in the following suggestions for cultural control which are essentially ecological in nature.

1. *Cnephasia* eggs are laid on rough wooden objects, from which first instar larvae are dispersed by the wind. The elimination of these objects, such as rough-barked trees, probably would reduce plant injury to the eastward under Willamette Valley conditions.
2. Grasses and grains escape larval mining. These plants are not susceptible to *Cnephasia* injury except in their late stages and only then in cases where another host is present to nurture the early larval stages of the "leaf-tier."
3. First instar larvae move downwards. Tall plants such as fruit trees and cane fruits are not injured by the smaller larvae. Older larvae feed on tender growing plant tissue and may ascend or descend to find it.
4. Ballooning larvae will starve on bare ground. This fact makes possible the culture of late-planted crops such as corn or potatoes without fear of *Cnephasia* injury provided the ground was free of plants at some time after the larvae were dispersed. Crops germinating early in the spring such as flax will be injured more or less seriously depending on the concentration of the larval population and the length of time the crops were exposed to drifting larvae.
6. Legume hosts favor an increase in *Cnephasia* populations. Flax injury by *Cnephasia* larvae averaged four times as much during 6 years of study when preceded by a legume as when preceded by a grain crop.—6-28-44.

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DR. MARSHALL SUCCEEDS DR. SWANSON AT MINNESOTA

Dr. Gustav Swanson, Associate Professor in Charge of Wildlife Management and Conservation at the University of Minnesota, has resigned to accept a position in the Fish and Wildlife Service of the United States Department of the Interior. Dr. Swanson has been succeeded by Dr. William H. Marshall, of Boise, Idaho, who took up his new duties January 1, 1945.

Insecticide Situation in the Pacific Northwest*

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Some 14,000,000 pounds of lead arsenate are used annually to protect the apple crop in the state of Washington from the codling moth. This is approximately 20 per cent of the 75,000,000 pounds estimated requirements for the United States as a whole in 1944.

Because of the quantity used, it is important to determine whether existing supplies for this year and for coming years are likely to be adequate, what the possibilities may be for utilizing other insecticides in whole or in part, and the limitations that may accompany the use of other materials. The problem is not simple.

Heavy spray schedules in recent years have led to the accumulation of excessive quantities of arsenic in orchard soils. This is particularly so in the irrigated regions of eastern Washington where there is very little leaching because of precipitation of less than ten inches a year. West of the Cascade Mountains and elsewhere in the state an accumulation of arsenic in orchard soil has been of little consequence. In fact, the amounts used to protect orchard crops have been far less in quantity. Where eight applications are necessary in a season to control orchard insects, as much as 400 pounds of lead arsenate may readily be added to orchard soil in a single year. In ten years' time, no less than two tons per acre may be accumulated.

While the figures for total arsenic in orchard soils are high, little difficulty is involved in growing cover crops in orchard soils until the quantity of soluble arsenic in the top six inches of soil is greater than three parts per million. On the other hand, orchard soils from which the trees have only recently been removed may have an accumulation of as much as 30 parts per million of soluble arsenic. According to some studies, the toxicity is directly proportional to the amount of water soluble arsenic present, rather than total arsenic, which may be 50 times as much.

None the less the opinion has been expressed that more and more of the total arsenic may become soluble arsenic, in turn making it difficult to grow cover crops in orchard soils or to grow other crops on lands where non-productive orchards have been removed. According to Vincent (1944) there are some 12,000 to 15,000 acres of ex-orchard land lying idle at the present time.

In order to compare "parts per million and pounds per acre" one doubles the first figure and expresses in pounds. There are approximately 2,000,000 pounds of dry soil in the surface six inches per acre. Vandecaveye *et al*, (1938).

From a standpoint of the accumulation of arsenic alone, certainly it is desirable for us to be alert to investigate other methods of attack by means of which materials less toxic to orchard soils may be utilized.

The matter of reducing the number of applications of lead arsenate in apple orchards as well as the possibility of lower concentrations has been given some study. So far there has not been much encouragement that essential savings in material may be effected by such means. There is less emphasis upon the amounts of lead arsenate needed to maintain protection from insect attack on the surface of the fruit throughout the season and progress has been made in more adequate timing of the early cover sprays.

For years our recommendation has been to apply the first cover spray eight days after the calyx spray. From studies made during the past five years it is believed that the first cover spray may be deferred for several days or a week's time. The fly in the ointment is that wind and rain may further delay the application of the first cover, and so defeat any attempt in the direction of better timing.

More information has been accumulated on the time interval between the peak of moth emergence as indicated by the use of traps in the orchard and the peak of worm entry, which may not occur until as much as 25 days later. It may be possible to save one cover spray by use of a more carefully planned timing procedure.

At the Tree Fruit Branch Experiment Station at Wenatchee, we are accumulating data to determine the possibility of utilizing accumulated day degrees of tem-

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perature to fix the time of the first cover spray, when it is necessary to have adequate spray protection on the surface of the fruits because of impending worm entry. If we can be reasonably sure that the first worm entry will occur when 163 day degrees, or some other fairly definite figure, have been accumulated, starting with the first steady emergence of moths, then we may be sure that ample protection is needed in terms of spray coverage. If such means of fixing spray dates are feasible, worm control may be enhanced and a saving of insecticide accomplished.

While there has been less emphasis on the maintenance of adequate spray protection throughout the season in terms of arsenic per square inch of apple surface, there is now greater emphasis on the utilization of light petroleum oils in the early cover sprays, especially where these may be valuable as ovicides. In the present state of our knowledge the addition of light oil is particularly valuable in the second and third cover sprays. With adequate timing, it is possible that oil could be utilized in the second cover spray alone if a greater time interval between the calyx and first cover spray may be permissible.

The use of light spray oils, as defined by the California State Department of Agriculture specifications, has been quite satisfactory when as little as two quarts are added to a cover spray of three pounds of lead arsenate in 100 gallons of water. Where there is a mite problem, however, it is necessary to increase the quantity of oil to three quarts.

The application of oils throughout the season is undesirable: first, because it is difficult to wash apples at harvest time and meet the federal tolerances, second, because of the danger of foliage injury. Little difficulty, however, has been encountered with the present tolerance of 0.05 grain of lead per pound, which has been in effect since 1940. The trend toward lighter oils again has reduced the chance for injury to foliage or fruits. On occasion, however, it may be necessary to choose between possible damage by the use of light oils or possible damage by reason of mites. In general, the addition of oil to lead arsenate sprays has not led to any great savings of lead arsenate used although there is greater efficiency in pest control.

The use of materials other than lead arsenate or cryolite in our apple orchards seems to be limited at present, although the results obtained by the use of a fixed nicotine by Newcomer and Cassill, U. S. Bureau of Entomology and Plant Quarantine laboratory at Yakima in 1943, are encouraging.

According to figures of the Washington State Department of Agriculture approximately 136,000 pounds of calcium arsenate was used in Washington in 1941. Most of this was for the control of potato flea beetles in Whatcom and Skagit counties on the coast and Kittitas and Yakima counties east of the Cascades. The amounts used in 1943 doubtless were greater, particularly in western Washington where a special attempt was made to control flea beetles and where the State Department of Agriculture employed extra help to advise growers on their dusting program throughout the season.

Calcium arsenate has been used in eastern Washington for flea beetle control, but may be replaced by cryolite following the experience of B. J. Landis, U. S. Bureau of Entomology and Plant Quarantine, who found cryolite somewhat superior to calcium arsenate for this purpose. Furthermore, Mr. Landis observed that his plots dusted with calcium arsenate in 1943 generally were much more infested with an aphis (*Myzus persicae*) as compared to other plots where cryolite was used as a dust. While the damage caused by aphids came late in the season and may not have been particularly serious, the insect may have been responsible for leaf curl disease, which was quite prevalent last year. Under the circumstances, it would seem that cryolite is preferable to calcium arsenate, at least in eastern Washington.

Cryolite: Investigations by different agencies have indicated that a high degree of codling moth control may be obtained by the use of cryolite in place of lead arsenate. From a standpoint of arsenic sick soils, the replacement of lead arsenate by cryolite is highly desirable. However, because of the fluorine tolerance of 0.02 grain per pound, in effect since November 14, 1938, it has not been possible to utilize cryolite in more than two applications and be reasonably sure of meeting federal tolerances.

The proposed tolerance of 7 mmg. per kilo. (approximately 0.05 grain per pound)

will be of great aid to the apple industry in the Pacific Northwest, even though it may not enable our growers to utilize cryolite throughout the season. In 1941, 1,580,754 pounds of cryolite were used in Washington. According to hearsay the quantity used was much higher in 1944, when the price to the grower was the same for cryolite as for lead arsenate.

Rotenone: In the Northwest, the greatest use of rotenone is for combating the pea weevil, because of the large acreage of dry edible peas in Washington and in Idaho. In addition, there is considerable acreage of green peas grown for canning in Oregon and in Washington. For the purpose of dusting dry edible peas in the Palouse area of Washington and Idaho more than 600 dusters were available for the 1944 season compared to 28 dusters in 1939. In 1943 and again in 1944, estimates were made in response to a request from the War Food Administration on the amount of rotenone necessary for pea weevils in the Pacific Northwest. Acreage figures were obtained from the AAA offices and the final estimates of the amounts needed were made by Messrs. W. E. Shull, entomologist, University of Idaho, T. A. Brindley, Bureau of Entomology and Plant Quarantine, Moscow, Idaho, Laurel G. Smith, extension entomologist and the present writer of the State College of Washington. These estimates were as follows:

	Washington	*Oregon*	*Idaho*	*Total*
Dry edible peas				
Acreage	370,000	85,000	313,000	768,000
Pounds 5% rotenone needed	252,833	58,083	213,885	524,800
Canning peas				
Acreage	45,500	35,400	600	81,500
Pounds 5% rotenone needed	137,878	107,272	1,818	246,968
Austrian peas				
Acreage	14,000			

Total estimated need in terms of raw root —771,768 pounds

In making these estimates the basis used was actual practice in the application of the dust as indicated by the AAA reports. This was necessary because in many cases only part of a field was dusted, or where weevil infestation was not apparent, not dusted at all. Dusting dry edible peas is desirable when the infestation averages one weevil in 25 sweeps of the insect net. In case of green peas for processing, it is desirable to dust early peas when the average amounts to one weevil in 250 sweeps of the net, late peas when the average is as low as one weevil in 500 sweeps.

When the rotenone content for newly mixed dust was limited to 0.5% in 1943, Palouse farmers generally increased the amount per acre from 10 pounds to 18 or 20 pounds. In other words, the real aim was to apply about the same amount of rotenone per acre as when a 1.0% dust was used. As revised for the 1944 season, the use of a 0.75% dust was permissible. Ground dusting with a canvas trailer 20 feet or more in length to hold the dust close to the plants has been highly successful in the Palouse country of eastern Washington and adjoining Idaho as well as in the Blue Mountain country of eastern Washington. So far dusting peas by airplane to control weevils has not been accompanied by any degree of success.

Rotenone is used in the cranberry industry in Pacific and Grays Harbor county where there are some 700 acres, all within two miles of the Pacific Ocean. Annual requirements are for 18,000 pounds of rotenone powder (4% rotenone) needed for six sprays to control fireworm, fruitworm and the cranberry tip worm.

This figure assumes sufficient pyrethrum for two applications for fruitworm adult control. If pyrethrum is available for only one application, then approximately 27,000 pounds of rotenone powder is needed in addition. Four pounds of 4% rotenone is considered equivalent to one quart of pyrethrum extract containing 2% pyrethrins.

Both rotenone and pyrethrum have been used in this area to combat cranberry insects. In severely infested bogs it is sometimes necessary to spray as many as eight times during the season, using 400 gallons of spray material per acre. Limited quantities of rotenone and pyrethrum were obtained for the 1944 season.

There are no satisfactory substitutes for these materials for the control of cranberry insects in western Washington. Nicotine sulfate was used by growers some years ago, but did not result in satisfactory control, perhaps because of low summer temperatures, and was supplanted by pyrethrum and rotenone sprays. Some 1500 pounds of cryolite were used in the Graylands area in 1943, although this was less efficient than the pyrethrum and rotenone combinations (pyrethrum in early season, rotenone later). Further-

more, there is danger of building up a spray residue of cryolite on cranberries difficult to remove if more than one application is made. Some 100,000 pounds of dehydrated cranberries were set aside for army use in the Graylands area in 1943.

Pyrethrum: Following our Experiment Station conference at Pullman, in January, 1944, estimates were made on the quantity of pyrethrum and rotenone needed for the cranberry industry for the season. This estimate was prepared by D. J. Crowley, Superintendent of the Cranberry-Blueberry Laboratory at Longbeach, Washington, Laurel G. Smith, extension entomologist, and the writer.

Cranberry growers normally use approximately 1500 gallons of pyrethrum extract containing 2% pyrethrins. This is equivalent to approximately 18,000 pounds of pyrethrum flowers containing 1.3% pyrethrins. Pyrethrum is necessary for the control of millers, especially adult moths of the fruitworm. In recent years growers have been using pyrethrum in at least two sprays.

One pyrethrum spray is regarded as an absolute minimum. This requires 900 gallons of pyrethrum extract containing 2% pyrethrins, equivalent to approximately 11,000 pounds pyrethrum flowers containing 1.3% pyrethrins.

Because of the scarcity of pyrethrum, the supply for the cranberry industry is inadequate. Cranberry growers were limited this year to 28% of the average quantity used in the area for the past four seasons. Not only that, but it was impossible to obtain the 2% concentrate used in previous years. Approximately 7600 pounds of a product containing 1% pyrethrins was purchased by the Cranberry Growers Association at Graylands for use this spring. So far in the season this has proven satisfactory and a further allotment was made late in June by War Production Board officials.

Nicotine: The use of nicotine in Washington is subject to considerable fluctuation depending upon insect outbreaks. According to our State Department of Agriculture figures, 141,821 pounds were used in the state for 1941. This includes, at least in part, considerable nicotine used in combating the pear psylla.

Some nicotine sulfate is used to combat the pea aphis, although there has been a tencency to prefer rotenone dust for that purpose. In the Yakima Valley a nicotine dust has been used to combat the squash bug. In western Washington again there has been some little use of nicotine on cabbage grown for seed, because of the cabbage aphis.

In some years, the rosy aphis causes considerable loss to commercial apples, but the occurrence of that insect is so irregular that it is difficult to know when to prepare for it. Rome apples were severely attacked in 1942 in many orchards, but the injury in 1943 was negligible. At the present time we do not believe it feasible to incorporate nicotine into the delayed dormant spray every year, because of the fact that damage by the rosy aphis only occurs once in five or six years. If we could foretell these outbreaks more accurately, such losses could be reduced.—10-20-44.

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DR. CARTER VISITS THE MAINLAND

Dr. Walter Carter, of the Pineapple Research Institute of Hawaii, has recently paid a visit to the mainland in the interest of the research program which he is conducting.

It must be a matter of regret to Dr. Carter's friends, that his visit did not coincide with the time of the Association Meetings at New York when more of them would have been able to greet him.

Methyl Bromide as a Fumigant for Dairy Factories[1]

E. M. Searls,[2] F. W. Fletcher,[3] and E. E. Kenaga[3]

Field investigations were conducted during the summers of 1942 and 1943 to determine the efficiency of methyl bromide as a dairy factory fumigant for controlling insect and rodent pests sometimes associated with this industry. A practical method of fumigation, involving a minimum of interference with normal factory operations, was developed. Tests were conducted throughout the cheese-producing areas of Wisconsin in representative commercial dairy plants and cold storage warehouses. Methods of preparing buildings for fumigation; various ways of applying the gas; and recommendations for dosages, circulation, ventilation, and safety precautions are presented.

Review of Literature.—Much of the literature on methyl bromide fumigation of dairy products deals with bromide residues and analytical methods for determining them in these foodstuffs. Roehm *et al.* (1943) adequately summarized this literature (Dudley *et al.* 1940; Dudley & Neal 1941; Laug 1941; Shrader *et al.* 1942; Stenger *et al.* 1939) and determined the residual bromide content of dehydrated skimmilk, butter, and several kinds of cheese after fumigation with methyl bromide under both laboratory and commercial conditions. It was found that after a reasonable aeration period, the residues were entirely inorganic in nature and were present in insignificant amounts indicating that all methyl bromide had disappeared.

There is little literature available relative to the use of methyl bromide for the control of dairy factory pests. However, Searls (1943a; 1943b) reported its possible value as a dairy plant fumigant.

A recent U.S.D.A. circular (*Anon.* 1943) indicates that dairy products as well as many other foods may be fumigated successfully with methyl bromide.

Spencer, *et al.* (1944), fed rats for one year on diets which contained 25 per cent whole milk powder, and which were fumigated with as much as 6 pounds of methyl bromide per 1000 cubic feet and then properly aerated for at least 48 hours. These rats showed no evidence of intoxication or nutritional deficiency as determined by hematological, histopathological, analytical, body weight, and organ weight studies. From this experimental work they concluded that "Foodstuffs fumigated with the usual commercial concentration of 1 to 2 pounds of methyl bromide per 1000 cubic feet" (for 24 hours' exposure) "and then properly aerated, will contain no residues which might have deleterious effects, even when such fumigated foods are included as a large part of the human dietary."

Structure of Dairy Plants in Relation to Fumigation.—In general there are two types of dairy plants to be considered from the standpoint of fumigation problems: cheese factories and cold storage warehouses.

Factories contain four more or less separate units: the milk intake, the make room, the curing room, and the combined boiler and coal rooms. In many of the older factories whey tanks are often located in an unfinished attic space above the make room.

The milk intake in most plants is difficult to seal for fumigation purposes, particularly around the roller tracks for the milk cans. The make room offers no particular difficulties in the preparation for fumigation except for the numerous ventilators that require sealing before the introduction of the gas. The curing room section of a cheese factory may or may not be recessed into a hillside. Those partially or wholly under ground have a lower leakage factor than those entirely above ground. There are usually two or three rooms in the curing room section, and this presents not only a distribution but also a ventilation problem. The boiler room and coal bin are often in a poor state of repair, and, along with the furnace, introduce a complicated sealing problem. Due to its loose type of construction, the attic storage or whey tank room is often difficult to seal and fumigate.

Some smaller cheese factories and other dairy plants have living quarters directly associated with them. This necessitates a

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special method of application and certain added precautions.

Cold-storage warehouses as compared to dairy factories have a much lower leakage factor because of better construction. These warehouses are rather difficult to ventilate because of cold temperatures and the small number of openings in the building.

FUMIGATION PROCEDURE—The first consideration in the general procedure was to determine if a practical fumigation was possible in a given dairy plant. This was accomplished by surveying each unit of a building and noting the general state of repair. If it was thought possible to seal the plant thoroughly, it was considered for fumigation. After this survey was completed the practical points in the procedure were considered in the following order:

Establishment of exposure periods.—The exposure period for dairy factory fumigations, from necessity, had to be relatively short in order not to interfere with the normal operations of the plant. Accordingly, all experiments were conducted at night with the exposure periods ranging between 5 and 12 hours. Cold storage warehouse fumigations were usually run over week ends, and in these cases all exposures were 24 hours in duration.

Determination and calculation of dosages.—In addition to the length of the exposure period and a knowledge of the general condition of a factory, certain other points had to be considered in determining the proper dosages of methyl bromide, such as inside temperatures, weather conditions, and species of pests. Past experience with this gas indicates that low temperatures, short exposure periods, poor state of repair of buildings, strong winds, and relatively resistant species of pests all require extra amounts of gas for satisfactory fumigation. Accordingly an attempt was made to conduct these fumigation tests over a wide range of conditions in order to test the limits of the usefulness of this fumigant. Once a dosage rate had been established, the dosage was calculated by dividing the cubic content of a building by 1000, then multiplying the quotient by the desired dosage in pounds per 1000 cubic feet. For example, at 1.5 pounds of methyl bromide per 1000 cubic feet, the dosage for 10,000 cubic feet of space is 15.0 pounds.

Sealing materials and methods.—Due to the high diffusibility of methyl bromide, buildings must be either tightly constructed or carefully sealed for successful fumigation. Various kinds of sealing materials and methods for applying them were tried in these tests. The size and shape of an opening to be closed determines to a large extent the type of sealing material to be used. Small orifices such as cracks and crevices in walls and around doors, windows, etc., were sealed with a number of substances, including wet shredded newspapers, an oil and flour mixture, wet rags, masking tape, putty, caulking compound, cement, and a mixture of calcium chloride 3 parts, asbestos 8 parts, and water 4 parts by weight.

Larger openings, such as broken windows, holes through walls, large wall areas with several small holes, porous walls, chimney flues, vents, intakes, doors, windows, etc., were covered with tar or asphalt building paper, untreated *Kraft* paper, oiled *Kraft* paper, red rosin paper, *Saran* film, wax paper, etc. Both external and internal methods of sealing such openings were tried.

Handling and distribution of test animals.—Test specimens used in these experiments were cheese skippers, *Piophila casei* L., cheese mites, *Tyroglyphus siro* L., and German cockroaches, *Blatella germanica* L. Each species was placed in a separate container. Ten skipper larvae and about 50 mites were placed in cotton-stoppered test tubes. About 15 cockroaches in various stages of development were confined in 4-ounce glass jars with metal caps, the centers of which were replaced with 60-mesh screens. Units composed of these three caged test organisms were usually placed near the ceiling, midway to the ceiling, and on the floor of each room. This placement of the test specimens was so made in order to check the effective distribution of methyl bromide throughout the building under fumigation. Some units were also located in spots where leakage of the fumigant was suspected, in order to render the test as rigorous as possible. Cockroaches and cheese skippers are seldom found in cold storage warehouses; therefore, they were usually not tested in such fumigations. All the test insects were reared under laboratory conditions. Where white rats and mice were used as test animals, three

different sizes of each were confined in wire screen cages. These cages were distributed in the same manner as the other units. The rodents were purchased from a biological supply house. Unfumigated animals were always maintained as a check on the mortality of the test specimens.

Precautions regarding dairy products and plant equipment.—Methyl bromide produces odors in certain materials, especially in sponge rubber, white kid leather, iodized salt stabilized with hyposulfite of soda (sodium thiosulfate) and some woolens; therefore, all of these items, when present, were removed from the factories before fumigation. All animal pets and plants were also removed. All flames, such as furnace fires and gas jets, were extinguished during the tests because of a possible chemical breakdown of methyl bromide which causes corrosion of metals.

Liquid methyl bromide was not allowed to come in contact with painted or varnished surfaces since it is a solvent for these materials.

Safety precautions.—In using methyl bromide, as well as all other fumigants, certain safety precautions must be exercised by the fumigators and others involved in the fumigation. The following precautions were taken:

1. A gas mask containing a black canister, type B, for organic vapors, was always worn in the presence of methyl bromide vapors. The exposure and concentration instructions as printed on the canister were rigidly followed.
2. Contact with liquid methyl bromide was avoided.
3. In the conduct of these fumigations two men always worked together.
4. All doors, windows, or other possible entrances were locked or barricaded before each test.
5. Warning signs were placed on all entrances of buildings under fumigation.
6. A halide leak detector was employed to determine when the fumigated building was free from gas before reoccupancy was permitted.

Introduction and distribution of methyl bromide.—The method of applying methyl bromide depended upon the volume of the space to be fumigated. When the space was small, the gas was liberated directly into the air from one-pound cans by means of a *Jiffy* applicator.[1] A shallow evaporating pan was used to catch the liquid where lacquered or varnished surfaces were present. Where a large space was to be fumigated, it was convenient to release the fumigant directly from 10-, 50-, or 175-pound cylinders. Methyl bromide was released systematically throughout the space to be fumigated, starting at the point most distant from the final exit and proceeding in such a manner that the fumigant did not interfere with retreat of the operator. Where there was danger of liquid methyl bromide coming in direct contact with foods, machinery, varnished or painted surfaces as found in living quarters and offices, it was sprayed against a burlap screen by means of a *Bean Majestic* spray nozzle with a No. 3 disc which was attached directly to the cylinder. (Fig. 1) A fan directed toward the screen carried the methyl bromide gas away and aided in distribution.

When available, a 12- or 15-inch fan was placed in each room under fumigation and allowed to run from 0.25 to 2.3 hours in order to assure complete distribution of the gas. The factory unit heater fans were also used for this purpose. All fans were turned on before the release of the gas in order to get the air in motion, and at the end of the circulation period they were turned off at the master electric switch.

Ventilation.—When a fumigation period was terminated, two people equipped with gas masks entered the building and opened all doors, windows, and other openings to provide cross-ventilation. The circulation fans were also turned on and used for ventilation. Buildings were ventilated from 30 minutes to 16 hours in order to determine the length of time required to free them from gas. Halide leak detectors (*Anon.*, 1943), obtained from refrigeration supply companies, were always used to detect the presence of methyl bromide. The halide leak detector was taken to all parts of a building to check areas difficult to ventilate; for instance, cold storage rooms, basement areas, closets, etc. Reoccupation of the fumigated space was permitted only after complete evaucation of the gas.

Checking results.—As soon as the halide leak detector indicated that the fumi-

[1] Manufactured by Arrow Products Co., Carlstadt, N. J.

Fig. 1. Apparatus used when contact with liquid methyl bromide is to be avoided.

gated buildings were safe for re-entry, all units of test animals were collected, examined, and the number and per cent dead were recorded. Due to the delayed lethal action of methyl bromide the test units were held under observation for 4 days. Final mortality was determined at the end of this period.

Odor and taste of all the dairy products were carefully checked before and after each fumigation.

DISCUSSION OF RESULTS.—The results of this investigation indicate that methyl bromide may be successfully employed for the control of pests in dairy factories and cold storage warehouses. Many interrelated factors, however, influence the results obtained from the use of this fumigant, as shown in table 1.

The type of building and its general state of repair are important limiting factors in methyl bromide fumigation. There is no accurate way of determining gas dosages necessary for the fumigation of dairy plants in a questionable state of repair. Experience is about the only aid in this respect. One of the main factors responsible for the unsatisfactory results in test No. 8 and in the whey tank and storage rooms in test No. 5 was the poor building condition. Fumigation was not attempted in certain factories because of poor state of repair; however, most plants could be sealed with little difficulty. The relatively good condition of the factories in test Nos. 2 and 9 and all of the warehouses (tests Nos. 10, 11, 12, 14, and 15) was responsible to a large extent for their successful fumigation. Factories recessed into hills lend themselves very well to fumigation since leakage of gas is greatly reduced. Where the total cubic content of a building is small in relation to the boundary areas, the leakage factor is pro-

portionately higher than where the reverse is true. Therefore, the dosage rates for small buildings should be higher than those for large structures of a similar type of construction. Living quarters directly associated with dairy plants also complicate fumigation procedures, necessitating of asbestos 8 parts, calcium chloride 3 parts, and water 4 parts. Due to the porous nature of *Kraft* paper, red rosin building paper, rags, and newspapers, and because of the rather poor results in fumigation tests Nos. 7, 8, and 9, in which they were used, they are not recommended as

Table 1.—Dairy plant fumigations with methyl bromide.

TEST NUMBER	TYPE OF DAIRY PLANT	SPACE, CU. FT.	LBS. PER 1000 CUBIC FEET	HOURS EXPOSURE	HOURS CIRCULATION	HOURS VENTILATION	TEMP. °F INSIDE	TEMP. °F OUTSIDE START	TEMP. °F OUTSIDE FINISH	BUILDING CONDITION	% MORTALITY TEST ANIMALS COCKROACH	SKIPPERS	MITES	MICE	RATS	GENERAL COMMENTS
	CHEESE FACTORY FUMIGATIONS UNDER WARM TEMPERATURES.															
1	American Cheese	12,000	1.67	8.0	0.5	1	68	62	57	Fair	100	0	100	—	—	Poor sealing materials and a light breeze.
2	American Cheese Make Rm	27,000	1.85	8.0	.25	1	82	77	59	Good	100	100	100	—	—	
	Intake Room	2,500	2.00	8.0	0.0	1	82	77	59	Good	100	100	100	—	—	
3	American Cheese & Butter															Low temperatures in
	Main part of factory	51,394	1.46	10.	.25	1	76	50	35	Fair	100	78	100	—	—	refrigerator & basement &
	Refrigeration Room						55	50	35		100	50	100	—	—	intake hard to seal
4	Limburger Cheese	10,747	1.80	12	1.0	5	70	57	49	Fair	—	100	100	—	—	Exposure longer than necessary
5	Swiss Cheese															
	Living Quarters	8,500	1.40	8.0	1.0	1	74	73	64	Fair	100	100	100	—	—	
	3 Curing Rooms	16,300	1.20	8.0	1.0	1	78	73	64	Excellent	100	100	100	—	—	Impractical to seal tightly
	Whey Tank & Storage Rms	12,000	1.70	8.0	0.0	1	80	73	64	Poor	100	83	100	—	—	due to poor construction
	Cool, Boiler & Make Rms	10,140	2.00	8.0	1.0	1	84	73	64	Fair	100	100	100	—	—	
6	Limburger Cheese	9,412	2.10	8.0	0.3	1	71	87	53	Fair	100	100	100	—	—	Dosage higher than necessary
	CHEESE FACTORY FUMIGATIONS UNDER COLD TEMPERATURES.															Dosages & exposure periods inadequate for such low temp.
7	Swiss Cheese															
	Living Quarters	8,500	1.80	7.5	0.5	2	50–55	45	42	Fair	100	0	—	—	—	
	Main part of factory	26,400	1.50	7.5	0.5	2	"	45	42	Fair	100	0	—	—	—	Poor sealing materials
	Whey Tank & Storage Rm	12,000	1.70	7.5	0.0	2	"	45	42	Poor	100	0	—	—	—	
8	Limburger Cheese	19,735	1.70	6.0	0.7	3	60	50	46	Poor	100	0	0	—	—	Poor sealing materials and a strong breeze
9	Swiss Cheese, Curing,															
	Boiling & Make Rooms	43,541	1.10	7.0	2.3	2	55–70	56	49	Good	100	25	—	—	—	Poor sealing materials
	Living Quarters	8,852	1.10	7.0	2.3	2	70	56	49	Fair	100	0	—	—	—	
	WAREHOUSE FUMIGATIONS.															
10	Warehouse	132,000	1.70	10.	1.5	1–2	82	77	59	Excellent	100	100	100	—	—	Cold storage warehouses easier to fumigate than cheese factories due to insulation
11	Warehouse, Cold Storage	24,087	1.25	24	1.0	8	57	57	49	Good	—	100	100	—	—	Cold storage fumigations
12	Warehouse, Cold Storage	20,000	0.75	24	2.0	16	54	62	51	Excellent	—	—	100	—	—	conducted under long exposure
	Cold Storage	20,000	0.75	24	2.0	16	54	62	51	Excellent	—	—	100	—	—	periods to compensate for
	Cold Storage	21,000	1.00	24	2.0	16	54	53	46	Excellent	—	—	100	—	—	low temperatures
	Cold Storage	21,000	1.00	24	2.0	16	54	53	46	Excellent	—	—	100	—	—	
	RODENT FUMIGATIONS.															
13	Swiss Cheese															
	2 Curing Rooms	9,650	0.30	5	0.3	0.5	76	75	76	Fair	—	—	—	—	100	Rodents very susceptable
14	Warehouse															to Methyl Bromide—only low
	Cold Storage	12,700	0.30	24	0.3	1	40	—	—	Excellent	—	—	—	—	100	concentration required
15	Warehouse															
	Curing Room	10,000	0.20	5	.25	1	64–70	85	87	Good	Top Floor	Ceiling Floor	25	100	0 100	Poor circulation
	Curing Room	10,000	0.20	5	.25	1	"	85	87	Good	Top Floor		—	100	100	Good circulation

added precautions. It is always well to fumigate an entire building rather than a portion of it in order to prevent immediate reinfestation from untreated sections.

Thorough sealing of all openings with impervious materials is essential for successful methyl bromide fumigation. A large number of sealing materials were tried in these tests, the following of which gave very satisfactory results: masking tape, waterproofed tar or asphalt building paper (Figs. 2 & 3), *Saran* film (Fig. 4), caulking compound, cement, wet shredded paper (Fig. 2), and a mixture composed sealing materials for methyl bromide. Although flour-oil paste is a good impervious sealing material, it did not adhere well in dairy plants because of the presence of excessive moisture. When possible, the external sealing of all doors, windows, and other openings is suggested, since more thorough control of pests inhabiting these areas can be obtained. It is to the advantage of the factory owner to repoint masonry, reputty windows, and repair all other openings previous to fumigation. In addition to preventing loss of fumigant, this also greatly reduces the possibility of

reinfestation. This point is particularly important in rodent control.

The profound effect which temperature exerts upon factory fumigations is readily noticeable in table 1, where the tests are grouped according to whether they were conducted under warm or cold temperature conditions. Good control of cockroaches resulted in tests Nos. 7, 8, and 9; however, practically none of the skippers and mites were killed. This was largely due to the relatively cold temperatures. Short exposure periods, unsatisfactory sealing materials, and a strong breeze in test No. 8 may also have been partially responsible for these results. It is desirable to maintain temperatures at 70° F. or higher during fumigations, especially those with short exposure periods (6 to 8 hours), as shown by the favorable results in tests Nos. 1, 2, 3, 4, 5, and 6. Successful fumigation is possible at lower temperatures but longer exposure periods or higher dosages, or both, are required.

In cold storage warehouse fumigation for mite control, it is advisable that temperatures be raised to at least 50° F., and that the exposure period be extended to

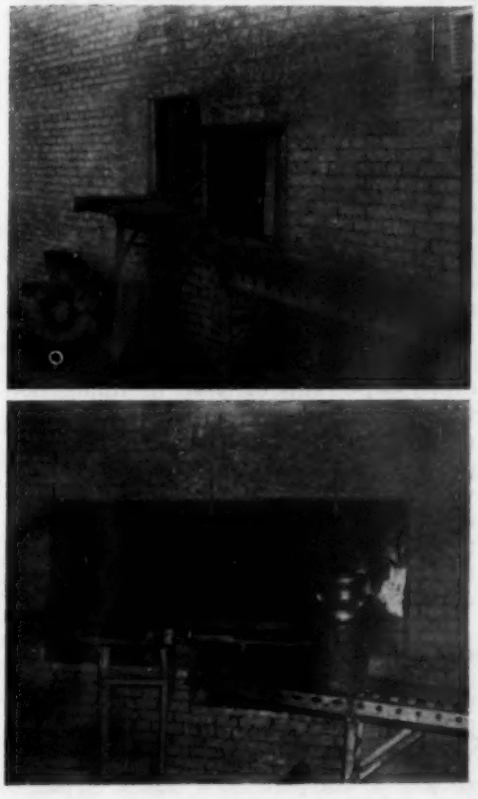

FIG. 2.—Milk intake with rollers packed with wet shredded newspapers, preparatory to sealing, (above), and (below) the same milk intake sealed with waterproof asphalt building paper and masking tape.

FIG. 3.—Door sealed with waterproof asphalt building paper and masking tape.

FIG. 4.—Ventilator sealed with transparent *Saran* film and masking tape.

24 hours. Excellent results were procured with concentrations of methyl bromide varying between 0.75 pounds and 1.25 pounds per 1000 cubic feet, as shown in tests Nos. 11 and 12. Excellent rodent control was secured in dairy plants and cold storage warehouses when the dosage of gas was 0.3 pounds per 1000 cubic feet and when the exposure periods were 5 and 24 hours respectively (tests Nos. 13 and 14). In the empty warehouse, where penetration and absorption were not limiting factors, only 0.2 pounds of the gas per 1000 cubic feet was necessary for control (No. 15). Higher concentrations are, of course, required in warehouses filled with merchandise. It is also interesting to note that the control of mice in test No. 14 was apparently not reduced by the low temperature of 40° F. This indicates the difference in response of mice, a warm-blooded animal, as compared to insects, which are cold-blooded.

Weather conditions sometimes influence the results of dairy plant fumigations. High wind velocity is an important factor since it increases leakage of the fumigant, especially in a loosely constructed building, as in test No. 8. Cold outside temperatures tend to lower the temperatures in factories, particularly where the boiler fires have been extinguished before fumigation. It is not advisable to fumigate for insects unless warm temperatures can be maintained in factory buildings.

The kinds of pests involved in a given control program determine to a large extent the dosage of methyl bromide, since pests vary in their resistance to this gas. The four most common destructive pests in dairy plants, listed in order of their decreasing resistance to methyl bromide, are: cheese skippers, roaches, cheese mites, and rodents (rats and mice). It is notable that rodents are very susceptible to this gas, being approximately only one-fifth as resistant as cheese skippers. Test No. 3 illustrates the relatively greater resistance of skippers as compared to roaches and mites. The susceptibility of rodents to methyl bromide is shown by the low dosages—namely, 0.2 to 0.3 pounds per 1000 cubic feet—required for their control. (Nos. 13, 14, and 15.)

One of the most important factors in satisfactory methyl bromide fumigation is adequate means of circulation to insure its proper distribution. Since methyl bromide is heavier than air it naturally tends to sink toward the floor unless properly circulated. Once it has been thoroughly distributed, it will not stratify. Depending upon the amount of obstruction to air currents, one 12- to 15-inch fan per 10,000 cubic feet of space should be sufficient to distribute methyl bromide gas properly in 30 minutes to one hour. The value of proper distribution is illustrated by test No. 15, which really represents two fumigations conducted under identical conditions, except that two fans were used in one case and only one in the other. Circulation with one fan gave incomplete distribution of the gas as evidenced by the fact that there was incomplete kill at the ceiling, while there was complete mortality on the floor. When two fans were used a complete kill on both floor and ceiling was attained. One precaution in the use of fans as well as with gas released from cylinders is to direct them away from all doors, windows, milk intakes and porous areas in general.

The length of the exposure period is another important variable in fumigation work. In this investigation an 8-hour exposure period (tests Nos. 1, 2, 5, and 6) proved to be satisfactory for dairy plants when fumigations were conducted at night in order not to interfere with plant operation. In warehouses where work stoppage was not a factor, a 24-hour exposure period at reduced dosages is recommended.

The length of the ventilation period after fumigation depends upon the type of dairy plant being fumigated. In cheese factories, creameries, etc., and where at least one 12- to 15-inch fan is used per 10,000 cubic feet of space, ventilation should be complete in 2 hours. A halide leak detector should always be used to detect the presence of methyl bromide, when determining whether buildings are or are not free from gas. In cold storage warehouses 8 hours of ventilation are usually required since they are more difficult to air out than factories.

In these studies no attempt was made to determine bromide residues in fumigated dairy products since this subject is adequately covered in literature. However, the possibility of changes in odor and taste in these foods was carefully checked, and no adverse effects were noted after fumigation. There was no

deleterious effect noticed on cheese starter, machinery, and other plant equipment.

With the foregoing in mind, table 2 can be used as a guide for methyl bromide fumigation of dairy plant pests.

If the sealing, circulation, weather conditions, and inside temperatures vary from those recommended, the dosage or exposure period must be varied accordingly.

While no actual mortality counts were made on houseflies, pomace flies, little houseflies, booklice, crickets, ants, pill bugs, and spiders, it was noted that they were readily controlled by methyl bromide fumigation. Spiders and ants seemed to be the most resistant forms.

Table 2.—Conditions of fumigation tests in dairy plants.

Pest	Type of Plant	Temp. °F.	Dosage #/1000 Cu. Ft.	Exposure Hours	Circulation Hours	Ventilation Hours
Cheese skipper	Cheese factory	80	1.25	8	0.5	2
Cheese skipper	Cheese factory	70	1.50	8	0.5	2
Cockroaches	Cheese factory	80	1.0	8	0.5	2
Cockroaches	Cheese factory	70	1.25	8	0.5	2
Cockroaches	Cheese factory	60	1.50	8	0.5	2
Cheese mite	Cheese factory	70	1.0	8	0.5	2
Cheese mite	Cold storage warehouse	50	0.75	24	1.0	8
Rodents	Processing	65–70	0.35	8	0.5	2
Rodents	Cold storage warehouse	40	0.3	24	1.0	8

SUMMARY AND CONCLUSIONS.—Fifteen methyl bromide fumigation tests were conducted in commercial dairy plants and cold storage warehouses in the cheese-producing areas of Wisconsin. With proper application, methyl bromide gave excellent control of cockroaches, cheese skippers, cheese mites, rats, and mice, as well as other minor pests of dairy plants and cold storage warehouses.

Practical methods were developed for treating these plants economically and with little interference to normal factory operations.

Methods are given for preparing buildings for fumigation, various ways of applying the gas, dosage requirements for various pests, and suggestions with regard to circulation of the gas and ventilation of buildings, as well as certain safety precautions.

No adverse effects were encountered from the use of methyl bromide either on dairy products or factory equipment.—11-16-44.*

* Early publication has been accorded this paper in consideration of the payment of the costs of publication.

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Post-War Entomological Problems[1]

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Post-war problems in entomology will include most, if not all, of the pre-war problems and many more. In times of peace there were many problems which awaited solution—some new and some old. There have been, however, but few attempts to state what the entomological problems are. It would be of interest, and perhaps of value, if at regular intervals the current entomological problems were listed as a matter of record. Had this been done in a systematic manner we would have a record of no little historical interest. The list made three decades ago would be very different from that which would have been prepared for the year preceding Pearl Harbor!

Most of the problems we were working on in 1942 are still with us and are what they were then. Much of our research effort since then has been directed to problems of wartime significance. The continuing pre-war problems could be profitably considered and they need to be. First, however, it is thought that consideration should be given to problems resulting from the war and those which are an outgrowth of war conditions and developments. Brief discussion of these, or some of them, is all that will be attempted at this time.

Reemployment and Placement.—From the standpoint of individual entomologists and through their potential accomplishments to the science of entomology it seems safe to say that the number one post-war entomological problem will be employment. Goodly numbers of trained entomologists are now in the armed services. More may be so engaged before peace is won. Many of those who have joined our fighting forces are assured that they will have the same or a comparable position when they are discharged. Others have no such assurance. In many cases temporary wartime appointments have been made to provide for continuance of the work of those who entered the services. Adjustments in assignments will cause disquieting uncertainties among many entomologists and many administrative headaches for those responsible for employment. This will be unfortunate for the individual. From the standpoint of the development of our science and getting the necessary work done, however, it may mean more and result in considerable loss. Delay in filling positions will interfere with continuous performance effort and interrupt research. It may even mean the loss of experimental results for one season. Advance planning and alertness on the part of administrators as well as a cooperative attitude and prompt responses to inquiries on the part of those returning will be needed to effect the transition with the least loss of productive accomplishment.

It is fair to assume that some of those who have entered the services may not wish to return to their former jobs. Others may wish to take advantage of the interruption of their pre-war work to secure additional training before returning to former lines of endeavor. Still others, who in their war activities have been doing entomological work, may find these activities more to their liking than what they did before the war. Many other factors may influence the actions and desires of those who return.

For those who elect to leave entomology, there is little that can be done by postwar planning. Such men can ease the responsibility of their former employers by promptly telling them of their decision.

For those who elect to take refresher courses or advanced training, there is much our colleges and universities can do to be ready to help hem. It is desirable that they lose no time in perfecting their plans. Returning entomologists who plan to secure additional training have the responsiblity of advising their former employers of their plans.

For the discharged entomologists who hope to continue in entomological work of the type they have carried on while in the armed services, there is much that we, as entomologists, can do which will help them and, at the same time, help our science. For the most part the entomological work that is being done by the armed

[1] Presented at the June 1944 meeting of the Pacific Slope Branch of the American Association of Economic Entomologists.

forces is a type of entomological endeavor that has received inadequate attention and support in the past. The war is doing much to prove the need for the benefits that can accrue from the control of insects which transmit diseases to man or attack and annoy him and reduce his efficiency. To a considerable extent entomologists have neglected this field. Not because we failed to recognize its importance, but because it did not provide opportunity for employment. In many of its aspects, this field is closely allied with public health activities. Where the activities are planned to secure protecting results, however, many of the operations must be based on entomology. The war has done much to prove this and to get the principle recognized. The identity of the insect is important, knowledge of its habits and how it may be controlled is essential. These are the basic principles that have long been applied in the control of insect pests of agriculture. It is entomology and we, as entomologists, must take an active part in this work—in many phases we should take the lead. If we do this we will help in the placement of returning entomologists. If we fail to do so we and our science will lose prestige and a place entomology is earning on merit of performance.

COMBATING INSECT VECTORS OF HUMAN DISEASES.—The global conflict in which we are engaged has sent our fighting men into all parts of the world. Abundant opportunity is thus provided for our soldiers and sailors to become infected with diseases not now prevalent within our country. Many of these diseases are transmitted by insects. That we do not know all the species of insects which may be vectors of these diseases is certain. It is entirely possible that some of the insects common to our country, may be able to carry some of the disease organisms that may be brought in by returning troops. In these cases the means by which the disease may become established within our country will already be provided. Entomologists and medical men will need to work together to keep ahead of—not behind—any such problems. The potential hazard here could have far-reaching effect and should not be ignored. The entomological problems in this field will be of outstanding postwar importance. They are significant now and are not being ignored by the entomologists.

New procedures for controlling many of the insects which are vectors of human diseases and the increasing recognition of the importance of these diseases to our economy suggests that more vigorous steps should be taken to combat them. An important part of any effort to suppress insect-borne diseases is the control of the insect vectors. This is basically applied entomology. The guidance, active association, and participation of entomologists in these undertakings will be indispensable.

Problems of combating insect vectors of diseases are not restricted to insects which, like mosquitoes, bite and fly away. They include those where the carrier lives most of the time on blood-giving hosts. The control of these vectors so far has been done, for the most part, with but little advice from entomologists. Entomologists have a part to play in these activities. Problems of controlling insect vectors of human diseases are with us now, but after the war they may well assume greater importance. Entomologists have a responsibility to help meet them. The war has provided recognition of our part in these activities. How we, in our science, act on and view these matters will have an important bearing on how we entomologists meet one of the important postwar entomological problems.

CONTROL RECOMMENDATIONS.—During the last two years entomologists have been advising farmers and civilians to use substitute means to control insect pests. In some cases our clients have been told that they should not use certain kinds of materials to combat pests on plants except as specified or to combat several kinds of pests on livestock.

This has been done as part of the effort to produce adequate quantities of important food and fiber. In recommending alternate or substitute control measures we have in many, if not most, cases recognized they were "second bests." This has had an important bearing on many phases of insect pest control and has been of special significance where insecticides are used. Some requirements have prescribed the strength at which the insecticide could be mixed for use. Frequently this has resulted in failure to secure expected control. There are places where effectiveness has been so reduced that materials have been used ineffectively or wasted.

Suggesting "second bests" and regimenting uses have aimed to do that which was best for the war effort and our common goal—victory. They have, at the same time, also created postwar problems for entomologists and the manufacturers of products used for insect-control. When supplies of materials that have been scarce become more plentiful, entomologists will need to be alert and advise that "first choice" insecticides should once more be used. They should also promptly make the needed adjustments in their recommendations on dosages and application rates. These should be those which will assure the best control with the least cost.

Two of the insecticides—pyrethrum and rotenone—which have been scarce were beginning to have extended agricultural use before the war. They are safe materials of proven value for many purposes. It is certain, however, that they were not, even then, used to the extent they should have been. In the post-war period we may again well renew our efforts to acquaint users of the value of materials such as these, which give effective control and do not leave objectionable residues.

This postwar problem which has risen as an outgrowth of war is, of course, not restricted to any one or two insecticidal materials, and before peace comes, the list may include some we now have in fair supply. The problem will involve not only the need to place the appropriate emphasis on first choice insecticides we now know, but also, the inclusion of an evaluation of these in comparison with new materials which have been developed or discovered in the war-time search for substitutes. We will all welcome the time when supply conditions will make tried materials available, so we will not have to recommend control measures not developed and proven by orderly research. Conclusions not based on adequate tests may be unsatisfactory. We all are familiar with the unfortunate effects that may follow failures of recommended methods. Such failures are bad for entomologists, insecticides recommended, producers of the materials, and the whole field of pest control.

In meeting the problem of making available to prospective users the best materials to control the numerous kinds of pests entomologists and insecticide chemists must work together. They must be aided by those who are trained in bringing recommendations to the users and by those who produce and sell the recommended materials. Cooperative, coordinated action is needed and there should be a joint understanding that satisfactory materials, and these only, will be recommended and supplied. Entomologists should take greater interest in the kind of insecticides offered as a basis of their research. To no small degree is this a part of their responsibility—they owe it to themselves and to the science. To carry this out they must, at all times, be exact in what they recommend and be specific as to dosages and rates of application. They expect this from others, yet much of our literature is vague and inadequate on these points. We all must keep clearly in mind that an insecticide can only be truly measured by the performance it gives to the user.—The farmer, the fruitgrower or the sanitarian, not merely the entomologist in his experiments.—The results at the end of the application is what counts. Research is not complete with laboratory and plot tests. It should include field trials with the type of equipment that will be used to apply the material in the way it will be handled under actual use.

RELATION BETWEEN INDUSTRY AND GOVERNMENT.—Since Pearl Harbor, entomologists in government and their coworkers in industry have cooperated more closely than ever before. This has been with a common aim and for a common good. Some of the results of cooperation have been surprisingly beneficial. The insect repellents now used by our troops were developed through such cooperation. The louse powder now used is another product of such cooperative effort. We are all proud of these developments and include them with numerous examples as illustrations of how all elements of our democracy can work and fight together against a common foe.

This very wartime cooperation between government and industry, and industry and government will be another of our post-war entomological problems. The patented and proprietary materials which have been recommended, procured, and used under trade names to protect our fighting men will be used to protect them as civilians. There are many civilians who are now awaiting the time when those improved insecticides may become available

to them. The framers of our Constitution provided for, and the early Congress enacted, laws to stimulate inventors and to permit them to protect their rights in their inventions. Our country had fought and won two wars before public funds were provided for research on insects. The research done through such means disclosed ways of controlling insects by the use of chemicals and provided the basic information for the development of our present insecticide industry. Many of the products the industry makes were developed and recommended for the purpose for which they are used through research supported by public funds. There is a good deal of conflict between the idea that public funds should be used to develop inventions that have to be produced by industry before they are available for use, and the idea that those who did the research for the public good should not refer to the product by the names under which it may be secured. There is also much which may be antagonistic to the public good when industry develops, produces, and markets something that is effective but the use of which is not directly recognized by the public servants who advise on pest control. The war has proved that such practices are not in the best interest of insect control and public welfare. One of the important postwar problems will be the development of sound, effective working basis between government and industry and industry and government. This must be based on mutual confidence and will be more easily possible if industry is organized sufficiently so it can be dealt with as a group. In thinking of research by government, we must also remember that its usefulness often depends on having industry to produce and market supplies and devices developed through research.

CURRENT FACTUAL INFORMATION ON INSECT PESTS.—For the past two crop seasons and during the present one, cooperative efforts have been made by entomologists and others to assemble and appraise information on the status of certain pests. These activities aimed to get salient facts together promptly and endeavored to anticipate the needs for applying control measures. Where infestations were developing and where there were local or regional needs for insecticides these facts were made available to those concerned with and responsible for supplies and their distribution. From a beginning, first with cotton insects which are controlled by calcium arsenate, the cooperative effort has extended to other important pests—particularly those controlled by materials the supplies of which are short. These activities have been very helpful in getting supplies to areas where needed in time to save crops and, especially in the case of screwworms, have contributed to controlling small outbreaks which would have been centers for spread.

This is not all that has been accomplished. Cooperating agencies have used the data assembled in advising farmers on when and how to control important pests. With the experience of two seasons the educational value of the assembled facts is having more extensive use this season, especially in the cotton-growing South. The service, expanded from old ideas and on a background of experience to meet wartime needs, has received general commendation. How to improve it, extend it to all important pests and areas, and to provide for its continuance, will be another postwar entomological problem. The part such surveys can play in conserving crops, materials, and labor and how they can contribute to the overall idea of preventive entomology has been clearly indicated. Entomologists should find ways to use knowledge and experience which is theirs to assure that insect pests will not continue to exact the present high toll from our agriculture. This is something *they* can do to help. Entomologists should develop and perfect ways to make it possible to prevent major infestations. Putting our little fires rather than fighting big fires may well become a postwar policy.

PRODUCTION AND PROTECTION OF QUALITY PRODUCTS.—When victory is won and hostilities cease, the trade in agricultural commodities will be resumed and expanded. How and where the numerous products we will produce may be marketed, falls in fields other than entomology. That there will be new markets and new ways of marketing is certain. We have only to think of the advances in transportation to be sure of this. Whatever the changes may be, it is certain that they will have an important bearing on entomology and the work of entomologists. It may well be that one of the aims

of our agriculture will be the production and marketing of quality products. This is a familiar slogan to you, members of this branch of our association—perhaps to a somewhat greater degree than in other parts of the country. Yet you are well aware of the losses caused by various pests and the cost of the control now secured. Should the demand for quality products increase—and history of our agriculture gives assurance that it will—the postwar problems of entomology will increase far more rapidly than they have in the past. Insect pests and diseases are factors of prime importance in the production and preservation of quality products. We entomologists know this only too well. There are, however, but few places where the importance of pest control is given emphasis comparable to that placed on soil preparation, variety selection, fertilization, and other fields of crop production. In the livestock and poultry field also, similar conditions exist. With the emphasis on quality entomologists may well recognize that many post-war problems will arise from and revolve around a demand for better ways whereby farmers and stockmen can produce products free from insects. The necessary corollary of this is that they be kept free. When we as investigators know how to do this, we will as extensionists still have the task of helping to inform the user how and when to do the job effectively.

PROTECTION FROM NEW PESTS.—The resumption of world trade will bring new and pressing problems in the field of plant quarantines. New products will be offered for consumption entry to be marketed, consumed or used in our country. More efficient means of transportation and continuance and extension of friendly relations with our neighbors and allies assure this. Inquiries of this nature are even now being made while means of transportation are still not available because of the war. Every effort must be made to prevent the entry and establishment of new plant pests; we already have too many. What pests may accompany new products is hard to foretell. To rest solely on an analysis of possible pest risk on the basis of what may now be known of those that are recorded for the country of origin can give protection of a sort. There is and will be a greater need for more complete knowledge of the insects associated with products offered for import. Insects and diseases of little or no significance in their native home may be of major importance in a new environment—witness the Japanese beetle. Some insects that are of apparent insignificance may be vectors of important diseases. How are we to meet these problems which are with us now and will be intensified? The intensification of problems of this nature in the post-war period will challenge the ingenuity of entomologists and quarantine officers. They cannot be met by adopting the attitude of exclusionists or isolationists. Cooperation, fact-finding surveys, and treatment methods may aid in the solution. We may also need to have more flexible regulations which will permit prompt control over infested products not specifically covered by existing plant quarantine orders.

As a part of these plant quarantine problems, current and post-war, we must not overlook those associated with the articles being shipped home by the hundreds of thousands of fighting men now in foreign lands. Important as these problems are now, with victory and accompanying demobilization they will be magnified manyfold. All of us at home should keep these potential pest hazards in mind, do what we can to acquaint others of the risk, and be on the watch for new pests. By these means we may help in the effort to prevent the introduction and establishment of new pests.

INSECT COLLECTIONS.—The extensive destruction of property in many of the lands where war is being and has been waged has, we know, caused losses to many prized collections. What this has meant and will mean to the collections of insects and the entomological institutions, it is much too early to state. Much of the work and progress in our science depends on accurate knowledge of the identity of the species of insects. One of the post-war problems that should receive early attention will be an analysis of losses of essential collections and an appraisal of what this means, if we are to continue to value the standard of comparison called "types" as we now do. Entomologists in all fields have an interest and stake in this post-war problem in the field of insect taxonomy—a problem which is a direct outgrowth of the war. Even though ways are found to "replace" lost "types," the lack of refer-

ence collections may long delay important entomological research unless this problem receives prompt attention and adequate support.

RESEARCH.—Entomology's contribution to the war has been made and is being made largely as a result of research. Many of the recent effective accomplishments have been made possible by applying the findings developed through careful studies which had been conducted over many years. The background of facts made it possible to supply needed answers for many problems in short order. What was known about some species suggests what to expect from others. Coordination of effort, combined knowledge and the experience of entomologists, provided many short cuts in the investigations needed to secure specific answers to wartime problems. This method of study has emphasized the advantages of pooling what is known about insects and having a unified set-up for entomological research. Performance and results during the war period have shown the kind of organizational pattern that should be used to produce results needed to solve post-war problems on insects that affect our economy.

Just as research has provided the basis for entomological accomplishment of the past and during the war we must look to it for the solution of many post-war entomological problems which have resulted from the war and war conditions. To these war-created problems we must add the numerous pre-war problems that remain unsolved. The importance of and need for research in entomology cannot be overemphasized. How to provide for, direct, and organize research on insects in the post-war period is a problem deserving prompt recognition and is one which should have a foremost place in post-war planning.

We have drawn heavily on the information assembled through pre-war research. A new background of facts needs to be assembled. Too much emphasis cannot be placed on the need for developing basic information on insects, how they develop, respond and behave in all environments. In addition to adequate research on insects there is urgent need for research to find answers for numerous specified problems where insects affect the health of man, or his possessions, agriculture or the resources on which our civilization depends. A partial list of the research problems that await study in all these various fields of entomological research could be assembled easily and promptly. Critical consideration will have to be given to appraise the relative importance of projects that should be included in any list. Care should be taken to see that all aspects of needed research are included and that important fields of entomology are not overlooked. To assign priority ratings would, no doubt, be unwise. The preparation of a list of important entomological problems where research should be carried out after the war is a task that the entomological profession may well undertake. Pointing out what needs to be done, and explaining why, may aid action agencies and inform the public and so crystallize needed support for research.

CONCLUSION.—Insects mean so much in the economy of our country—both beneficially and destructively—and they affect man, his possessions, crops, and livestock in so many ways that we need have no fears for the continuance of our science and our profession. The general public's appreciation of entomology—even though they may not use that word—has advanced materially because of the war. Even in prewar days various segments of the public have done much to support our work. We need all the support that can be mustered. More than this, we need confidence in ourselves, conviction of the importance of our problems, realization and recognition of the field of entomology, and a will to take our place in doing what should be done to control and utilize insects for the improvement of health, comfort and the advancement of world economy. We must cooperate among ourselves, and with others and remember that science has no place for selfishness. If this is done our postwar entomological problems will be solved. In solving them, we will need more—not fewer—entomologists Employment and placement of entomologists will be a "straw man" rather than what was said in the beginning—a top-ranking postwar problem.—10-7-44.

Thomas Jefferson and Economic Entomology[1]

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Many accounts appeared during 1943 and 1944 upon the 200th anniversary of Thomas Jefferson's birth, honoring him as a statesman, as a philosopher, as author of the Declaration of Independence, as a farmer, as an educator, etc., and rediscovering his interest in law, economics, architecture, ethnology, chemistry, botany, physics, and other subjects, all testifying to his great versatility. In the present article it is not my intention to claim that Jefferson was an economic entomologist, but rather to present evidence from his writings demonstrating his interest in economic insects. Such evidence as my limited facilities have permitted me to collect has been gathered from the several printed sources noted in the references, and I have only brought it together in one place. Jefferson's interest in economic insects may have been greater than is here indicated, but this will not be known until all his writings, including thousands of letters, have been published, an undertaking now in progress under the editorship of Dr. Julian S. Boyd, librarian of Princeton University, and involving the publication of 52 volumes over a period of years, by Princeton University Press.

The first reference to insects, in Jefferson's writings, that has come to my notice, occurs in his "Account Book," under 1775, and this relates to the periodical cicada, as follows.

"Dr. Walker sais he remembers that the years 1724 and 1741 were great locust years, we all remember that 1758 was and now they are come again this year 1775, it appears then that they come periodically once in 17 years. They come out of the ground from a prodigious depth. It is thought that they eat nothing while in this state, laying their eggs in the small twigs of trees seems to be their only business. The females make a noise well known. The males are silent."

In Jefferson's "Notes on the State of Virginia," written in 1784, we find the following references to insects, these being from the third American edition, published in New York in 1801.

Page 58. "The silk-worm is a native, and the mulberry, proper for its food, grows kindly."

Page 248. "We find it easier to make an hundred bushels of wheat than a thousand weight of tobacco, and they are worth more when made. The weavil indeed is a formidable obstacle to the cultivation of this grain with us. But principles are already known which must lead to a remedy. Thus a certain degree of heat, to wit, that of common air in summer, is necessary to hatch the egg. If subterranean granaries, or others, therefore, can be contrived below that temperature, the evil will be cured by cold. A degree of heat beyond that which hatches the egg we know will kill it. But in aiming at this we easily run into that which produces putrefaction. To produce putrefaction, however, three agents are requisite, heat, moisture, and the external air. If the absence of any one of these be secured, the other two may safely be admitted. Heat is the one we want. Moisture, then, or external air, must be excluded. The former has been done by exposing the grain in kilns to the action of fire, which produces heat, and extracts moisture at the same time; the latter, by putting the grain into hogsheads covering it with a coating of lime, and heading it up. In this situation its bulk produced a heat sufficient to kill the egg; the moisture is suffered to remain indeed, but the external air is excluded. A nicer operation yet has been attempted; that is, to produce an intermediate temperature of heat between that which kills the egg, and that which produces putrefaction. The threshing the grain as soon as it is cut, and laying it in its chaff in large heaps, has been found very near to hit this temperature, though not perfectly, nor always. The heap generates heat sufficient to kill most of the eggs, whilst the chaff commonly restrains it from rising into putrefaction. But all these methods abridge too much the quantity which the farmer can manage, and enable other countries to undersell him which are not infested with this insect."

[1] This paper was prepared at the request of Dr. E. O. Essig, President, American Association of Economic Entomologists. The Association was invited by the Secretary of Agriculture to participate in the national activities honoring Thomas Jefferson in 1943, the two hundredth anniversary of his birth.

The "weavil" referred to by Jefferson was the Angoumois grain moth, *Sitotroga cerealella* (Oliver), a pest referred to by earlier American writers as the "fly-weevil." In the following and last quotation from "Notes on the State of Virginia," Jefferson writes of the lack of information on insects and of the origin of the honey bee.

Page 109. "Of our fish and insects there has been nothing like a full description or collection. More of them are described in Catesby than in any other work. Many also are to be found in Sir Hans Sloane's Jamaica, as being common to that and this country. The honey-bee is not a native of our continent. Marcgrave indeed mentions a species of honey-bee in Brazil. But this has no sting and is therefore different from the one we have, which resembles perfectly that of Europe. The Indians concur with us in the tradition that it was brought from Europe; but when, and by whom, we know not. The bees have generally extended themselves into the country, a little in advance of the white settlers. The Indians therefore call them the white man's fly, and consider their approach as indicating the approach of the settlements of the whites. A question here occurs, how far northwardly have these insects been found? That they are unknown in Lapland, I infer from Scheffer's information, that the Laplanders eat the pine bark, prepared in a certain way, instead of those things sweetened with sugar. 'Hoc comedunt pro "rebus saccharo conditis." ' Scheff. Lapp. c. 18. Certainly if they had honey, it would be a better substitute for sugar than any preparation of the pine bark. Kalm tells us the honey-bee cannot live through the winter in Canada. They furnish then an additional proof of the remarkable fact first observed by the Count de Buffon, and which has thrown such a blaze of light on the field of natural history, that no animals are found in both continents, but those which are able to bear the cold of those regions where they probably join."

In "The Writings of Thomas Jefferson" edited by H. A. Washington a few more references to insects may be found. Writing from Paris, March 24, 1789, Jefferson acknowledges Willard's letter sending him a diploma for a Doctorate of Laws, which Harvard University had conferred upon him and among other matters, states that "The Botany of America is far from being exhausted, its Minerology is untouched, and its Natural History or Zoology, totally mistaken and misrepresented" (Washington, vol. 3, p. 14).

In another letter written from Paris, May 10, 1789 to General Washington, Jefferson includes the following extract from a letter he had received from Thomas Paine, "The acts for regulating the trade with America are to be continued as last year. A paper from the Privy Council respecting the American fly, is before parliament. I had some conversation with Sir Joseph Banks upon this subject, as he was the person whom the Privy Council referred to. I told him that the Hessian fly attacked only the green plant, and did not exist in the dry grain. He said, that with respect to the Hessian fly, they had no apprehension, but it was the weevil they alluded to. I told him the weevil had always, more or less, been in the wheat countries of America, and that if the prohibition was on that account, it was as necessary fifty or sixty years as now; that I believed it was only a political maneuvre of the ministry to please the landed interest, as a balance for prohibiting the exportation of wool, to please the manufacturing interest. . . . If you are writing to General Washington, it may not be amiss to mention this" (Washington, vol. 3, p. 29).

The same subject is pursued further in Jefferson's letter to Mr. Vaughan from Paris, May 17, 1789.

"Your nation is very far from the liberality that treatise inculcates. [speaking of a book on trade]. The proposed regulation on the subject of our wheat, is one proof. The prohibition of it in England would, of itself, be of no great moment, because I do not know that it is much sent there. But it is the publishing a libel on our wheat, sanctioned with the name of parliament, and which can have no object but to do us injury, by spreading a groundless alarm in those countries of Europe where our wheat is constantly and kindly received. It is a mere assassination. If the insect they pretend to fear, be the Hessian fly, it never existed in the grain. If it be the weevil, our grain always had that; and the experience of a century has proved that either the climate of England is not warm enough to hatch the egg and continue the race, or that some other un-

known cause prevents any evil from it" (Washington, vol. 3, p. 38).

At this time, the Hessian fly, *Phytophaga destructor* (Say), was a national problem, in view of its widespread damage to wheat, and a subject of much discussion. On April 15, 1791, at a meeting of the American Philosophical Society, on motion of Mr. Jefferson, then Secretary of State in President Washington's cabinet, it was "Resolved that a select committee be appointed to collect and communicate to the Society, materials for forming the natural history of the insect usually called the Hessian fly. As also information of the best means of preventing or destroying the insect; and whatever else relative to the same may be interesting to Agriculture." In addition to Mr. Jefferson, the committee consisted of Benjamin Smith Barton, Dr. Wilkinson, Mr. Charles Thompson, and Dr. Caspar Wistar. At a meeting of the Society, on August 19, 1791, "a short memoir on the wheat insect, or Hessian fly, by Mr. S. L. Mitchill of Long Island, in a letter to Mr. John Vaughan was read."

Charles A. Browne in his recent study "Thomas Jefferson and the Scientific Trends of His Time" (Chronica Botanica Reprints, No. 1, Nov. 1943, p. 28) writes —"It should be noted in passing that this subject [the Hessian fly] had been previously considered by the Society, the Committee on Husbandry, at the meeting of May 18, 1768, having recommended that it consider 'whether any method can be fallen upon for preventing the damage done to wheat by the Hessian fly.' This was seven years before the Revolution, so the supposition that this insect (Phytophaga destructor) derived its popular name from having been introduced into the United States in imported straw used as bedding for Hessian troops during the Revolutionary War is manifestly incorrect."

My understanding of the matter is, that at the May 18, 1768 meeting of the American Philosophical Society, it was recommended that the Committee of Husbandry meet on May 31, "to consider whether any Method can be fallen upon for preventing the Damage to Wheat by what is called the Fly." At the June 21, 1768 meeting of the Society the Committee on Husbandry reported that "they had considered ye affair of destroying the fly in wheat and that Dr. Bond had laid before them a paper containing many useful observations on the subject; which Dr. Bond was requested to read before the society." At the November 15, 1768 meeting of the Society "Colonel Lee transmitted to the Society, the ingenious and accurate observations of Colonel Landon Carter of Sabine-Hall in Virginia concerning the fly-weavil that destroys the wheat." In the Transactions of the Society (vol. 1, Sec. 2, p. 205–17) Colonel Carter's paper is entitled "Observations concerning the fly-weavil that destroys the wheat, with some useful discoveries and conclusions, concerning the propagation and progress of that pernicious insect, and the methods to be used to prevent the destruction of the grain by it."

Following Carter's paper is the report of the Committee on Husbandry, which states that the injury by the "fly-weevil" started in North Carolina 40 years before and extended into Virginia, Maryland and the lower part of Delaware. The committee also called attention to the similarity of the American insect to an insect which a gentleman of Angumois described in Europe. From reading Carter's paper and the report of the Committee on Husbandry, it is apparent that the "fly-weevil" was the Angumois grain moth Sitotroga cerealella Oliv.

Because the word "Hessian" is not used in any of the 1768 reports of the Society or of the Committee on Husbandry and because Colonel Carter's paper and the report of the Committee on Husbandry both describe the work of an insect that couldn't possibly be the Hessian fly, it is apparent that "the fly" and the "fly-weevil" refer to the Angumois grain moth and that the Hessian fly was not considered by the American Philosophical Society until 1791 when it was made the subject of study by Jefferson's committee, which unfortunately did not report back to the Society. At least there is no official record of it having done so. An account in the Proceedings of the Biological Society of Washington, vol. iv, p. 39, states that in the committee report, "which was accompanied by large drawings, the history of the little marauder was given in considerable detail."

On May 1, 1791, from Philadelphia, Jefferson wrote to Thomas Mann Randolph as follows about the Hessian fly and

the Angumois grain moth. Bartram, of course, was wrong in assuming that the "weavil" of Virginia was the same one that was injuring peaches, plums, etc., in the vicinity of Philadelphia.

". . . A committee of the Philosophical Society is charged with collecting material for the natural history of the Hessian fly. I do not think that of the weavil [sic] of Virginia has been yet sufficiently detailed. What do you think of beginning to turn your attention to this insect, in order to give its history to the Phil. society? It would require some summer's observations.—Bartram here tells me that it is one & the same insect which by depositing its egg in the young plumbs, apricots, nectarines & peaches renders them gummy & good for nothing. He promises to shew me the insect this summer. I long to be free for pursuits of this kind instead of the detestable ones in which I am now labouring without pleasure to myself, or profit to others. . . ." (Ford, Jefferson 6: 250–251).

Apparently Jefferson's friends and acquaintances did not hesitate to write to him about injurious insects, especially in view of his interest in things agricultural and in view of the importance of agriculture at that time. Thomas Mann Randolph, writing from Monticello on June 13, 1793, to Jefferson, tells him, among other things, of his insect troubles.

". . . Our young vegetables have been separated from the root under ground by grubs, or eaten in the seed-leaf by a very minute tribe of grasshopper, and two species of still more minute volatile insects, or devoured in whole squares when farther advanced by immence [sic] swarms of insects resembling a good deal the fire-fly tho wanting its phosphorous. Having once had some little technical knowledge in Entomology, I felt a curiosity to ascertain the families to which these different insects belong, but from the insufficiency of Linnaeuses description, and the smallness of the subjects, I have not been able to satisfy it. The earth is alive with these creatures this summer owing I suppose to their being spared by the frost last winter. . . ." (Jefferson Papers, M. H. S.).

Randolph's grubs were no doubt the larvae of Lachnosterna or some other genus of Scarabæidæ. His "minute tribe of grasshopper" could have been leaf-hoppers, or garden flea-hoppers (*Halticus*) and his "two species of minute volatile insects" may have been flea beetles. The swarms of insects resembling fire-flies were no doubt blister beetles (Meloidae).

Both the Hessian fly and the Angumois grain moth are mentioned frequently in letters between Jefferson and his numerous correspondents. On June 13, 1793, Jefferson wrote to Gouverneur Morris saying, ". . . Though our spring has been cold and wet, yet the crops of small grain are as promising as they have ever been seen. The Hessian fly, however, to the north and the weavil [sic] to the south of the Potomac, will probably abridge the quantity . . ." (Lipscomb and Bergh, Jefferson 9: 125). On July 31 and August 14, 1793, letters from Thomas Mann Randolph to Jefferson, from Monticello, both mention the "weavil" in wheat and discuss the effects of rotations and dry weather upon it (Jefferson Papers, M. H. S.). And in 1795, August 11, Jefferson wrote to Randolph from Monticello, mentioning the wet weather during planting time and saying the weavil [sic] is very generally apprehended" (Jefferson Papers L. C.).

In his Travels through the United States of North America, in the Years 1795, 1796, 1797" the Duke de la Rochefoucald-Liancourt, of France, wrote of Jefferson's farming practices and mentions 'a worm, whose eggs are almost constantly deposited in the ear of the grain," making it necessary to thresh the corn [wheat] a short time after the harvest; in this case the heat occasioned by the mixture of the grain with its envelope, from which it is disengaged, but with which it continues mixed, destroys the vital principle of the egg, and protects the corn [wheat] from the inconveniences of its being hatched." . . . This scourge, however, spreads no further northward than the Potomac, and is bounded to the west by the Blue Mountains."

From Washington, on June 19, 1803, Jefferson wrote to John W. Eppes, saying ". . . I have examined your Hessian flies & find them very genuine on which I condole with you. . . . the advantageous remedy is to sow no more wheat grounds than can be well manured & sowing the yellow bearded wheat, the surplus grounds put into rye and clover. They attack barley more readily than wheat. when they drive us to this, they are a great blessing . . ." (Jefferson Papers U. Va.).

What was apparently a species of army worm is mentioned in Jefferson's letter of July 1, 1806 to James Maury. ". . . We have been lately alarmed with the appearance of caterpillars which at first threatened destruction to our small grain, Indian corn, tobacco & grasses. it has happily however disappeared after little injury. . . ." (Jefferson Papers L. C.).

John P. VanNess sent two "worms" to

Jefferson on July 5, 1806, together with a note saying that they had come from a Lombardy poplar tree and that they answered the description of a "reptile" which infested ornamental trees and was thought to be poisonous. Mr. VanNess believed Jefferson would be glad to see them. (Jefferson Papers, Missouri). In 1807 the "Medical Repository," (vol. 10, No. 1, p. 98–100) carried an anonymous paper entitled "History of the worm which spreads terror through New York and the neighboring states, in June and July, 1806." The article states that after the eclipse of June 16 and before the festivity of July 4, there was a considerable dearth of foreign and domestic news, and so the newspapers discovered a worm on Lombardy poplars and made it into one of the most poisonous of all reptiles. Tales were spread that dozens of men, women and children, had been killed by its bite. The cause of all this excitement was a species of Phalaena. In the "Philadelphia Medical and Physical Journal" for 1807, (Suppl. 1, Mar. 7, Sect. 2, art. 6, p. 139–57) Dr. John B. Davidge wrote more about this poplar caterpillar, and quoted the experiments of European authors with nettling caterpillars. Apparently this is the insect that VanNess sent to Jefferson.

The "Philadelphia Medical and Physical Journal" of 1806, (part II, vol. II, p. 90–9) carried "A memoir on the treatment of the silkworm," by Mr. Robert Lowry of Siena, that had been first sent to Mr. Jefferson, President of the United States, then referred by him to the American Philosophical Society and finally sent by this Society to the editor of the Journal in which it appeared.

In 1807, from Washington, Jefferson wrote to James Maury saying, " . . . The crops of the present year have been great beyond example. The wheat sown for the ensuing year is in a great measure destroyed by the drought and the fly . . . " (Lipscomb & Bergh, Jefferson, 11, 397).

In Jefferson's summary of his meteorological journal for the years from 1810 through 1816, at Monticello, he notes the first appearance, of the blossoms of various plants, of birds, of insects, etc., and his entomological observations are—"Fireflies appear May 8; The tick appears Mar. 15 to April 2; The sawyer first hear June 14 to July 20" (Betts, p. 627). And in his scheme for a system of agricultural societies, March, 1811, he includes a list of subjects worthy of the attention of the proposed societies including, . . . " The care and services of useful animals for the saddle or draught, for food or clothing, and the destruction of noxious quadrupeds, fowls, insects and reptiles" (Betts, p. 641).

From 1811 to 1817, in letters that Jefferson wrote to James Monroe, Charles Bankhead, James Madison and William Johnson, there are brief references to the Hessian fly and its injuries. These are all recorded by Betts. And in Jefferson's "Farm Book" there is an entry on May 3, 1814 stating that the period for sowing wheat is from October 10 to November 10 and that wheat sown either earlier or later is subject to the "fly."

Although Jefferson never, publicly or in writing, criticized his associates in the Philosophical Society, of which he was president for years, Gilbert Chinard in a recent paper has found one exception to this policy. Jefferson, writing to William Wirt on August 5, 1815, expressed himself as follows. "Landon Carter's measure you may take from the first volume of the American Philosophical transactions, where he has one or more long papers on the weavil, [sic] and perhaps other subjects. His speeches, like his writings were dull, vapid, verbose, egotistical, smooth as the lullaby of the nurse, and commanding like that, the repose only of the hearer."

Writing from Monticello, April 11, 1818, to Jacob Bigelow, about climate, Jefferson mentioned the weather records that he had kept for seven years, including the flowering and fruiting dates for various plants, the occurrence of insects, etc., and gave Bigelow a sample which included the following:

"The tick appears Mar. 15–Apr. 2.

"Fireflies appear May 8.

"Katydids or sawyers heard July 15–20."

And finally in Jefferson's "Farm Book" there appears this record,—"1824 Apr. Gen[1]. Cocks says the Peach tree worm is hatching all July, Aug. Sep. and lays its egg immediately on being hatched. it may be seen and taken out from Mar. to June. it should always be done before harvest" (Betts, p. 612).

It has been said by others, that, of Jefferson's varied interests, agriculture occu-

pied his thought and attention the most, and he carried on, with his contemporaries an extensive correspondence about agricultural subjects. In view of this it was natural for him to pay some attention to the insect pests of crops in which he was interested, especially as they reduced yields and gave no end of trouble. In addition, his library, according to Edwards, included works on entomology and beekeeping. Although his interest in botany, chemistry, mineralogy, etc., and to a lesser extent entomology was mainly utilitarian and designed to serve practical ends, it appears that he endeavored to possess an intelligent understanding of the subjects within his interest.

The references to insects, in his writings that have been quoted occur over a period of fifty years or from 1775 to 1824. American entomology during this period was nothing to boast about. Although a few papers on entomological subjects appeared before 1775 and later in the transactions of the American Philosophical Society and other journals and although entomological observations were being made by travelers, it was not until 1795 that William Dandridge Peck published his first paper on entomology and not until 1806 that Melsheimer's "Catalogue of the Insects of Pennsylvania" appeared. Rafinesque described aphids in 1817 and in the same year Thomas Say's first paper was published. In 1823, T. W. Harris was just getting started. American farm journals date from 1819 when the American Farmer was established at Boston. All in all, American entomology was only a thin trickle during Jefferson's life time, and entomologists were few and far between. Although Jefferson was not an entomologist, he was, so far as I know, the only president of the United States who thought seriously enough about insects to write about them in his letters and to stress the need for more specific study of them.—9-20-44.

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INSECTICIDE REPORTS AVAILABLE

The Chemical Unit of the Department of Commerce has recently prepared reports on certain insecticides of economic importance, pyrethrum, rotenone, nicotine, lead arsenate and calcium arsenate.

Each report is issued as a synopsis of information which embraces a number of topics, including a description, statement of uses, production data and imports and exports. The main purpose of these synopses is to bring up to date all available statistical information and it is believed that for this reason they will be of interest to persons dealing with insecticides.

Persons desiring copies may secure them on request from the Chemical Unit of the Department of Commerce, Washington, D. C. There is no charge.

(The above is the substance of a statement sent to Dr. E. N. Cory by Dr. L. N. Markwood, for inclusion in the *Journal*.)

SCIENTIFIC NOTES

Concentrations of Sodium Fluoride-Flour Mixtures for Silverfish Control

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Pest control operators often use a bait containing sodium fluoride and wheat flour for the control of silverfish. An experiment was conducted in the laboratory in Los Angeles in order to determine what concentrations of the sodium fluoride-flour mixture were most effective against *Ctenolepisma urbana* Slabaugh.

Traps were prepared as previously described (Mallis, 1941) by binding the outside surface of one ounce salve jars with scotch masking tape. A teaspoonful of the material being tested was placed in each trap. These traps were then distributed beneath an auditorium in West Los Angeles which was badly infested with *Ctenolepisma urbana*. The jars were removed at 24 hour intervals, and those containing *C. urbana* were kept at room temperature during the observation period. The results are indicated in table 1.

Table 1.—Mean length of life, in days after entering trap, of *Ctenolepisma urbana* exposed to varying concentrations of sodium fluoride in a sodium fluoride-flour dry mixture.

Formulation	No. of Silverfish	Life in Days After Entering Trap[1]
Flour check	55	27.4
1 NaF:99 Flour	62	10.6
3 NaF:97 Flour	51	6.7
5 NaF:95 Flour	58	4.3
7 NaF:93 Flour	64	5.6
9 NaF:91 Flour	51	4.4
10 NaF:90 Flour	26	3.9
30 NaF:70 Flour	29	5.2
50 NaF:50 Flour	25	4.6
70 NaF:30 Flour	25	4.0
90 NaF:10 Flour	25	3.9
100 NaF	10	4.7

[1] 4.1 days required for minimum significance (determined by J. C. Elmore).

It will be noted that there is no significant difference in concentrations above 1 per cent sodium fluoride, and that the mean length of life after entering trap varied relatively little at concentrations above 5 per cent sodium fluoride. On the basis of these results it is recommended that the sodium fluoride-flour mixture contain no more than 5 per cent sodium fluoride. Many of the baits now in use contain as much as 30 per cent sodium fluoride.

Experience in silverfish control has shown that for best results the dry bait should be thoroughly mixed and then distributed in "pinches" at 1 to 3 foot intervals behind molding, in cracks and crevices, in the corners of book cases, etc. Application of this mixture in several badly infested buildings apparently gradually decreased the silverfish population.—8-22-44.

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Toxicity of DDT and Pyrethrum to *Chaoborus punctipennis*[1]

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The new insecticide DDT (2,2-bis(p-chlorophenyl)-1,1,1-trichloroethane) has been tested in the laboratory against larvae and pupae of *Chaoborus punctipennis* Say.[3] Larvae in the overwintering stage were seined in February 1943 from Lake Lawsona in Orlando, Fla. Tests were made at room temperature with 15 larvae or pupae in beakers containing 250 ml. of tap water, by a method similar to that commonly used for laboratory testing of culicene larvicides. All tests were in duplicate with three replications at each concentration. DDT and a pyrethrum extract containing 20 per cent of pyrethrins were dissolved in acetone, and appropriate dilutions were mixed with water in the test beakers. Mortality readings were taken after 48 hours. For controls larvae and pupae were kept in beakers containing 250 ml. of water plus 1 ml. of acetone (representing the average amount of acetone in the test beakers). There was no mortality in any of the controls during the 48-hour observation period.

Table 1.—Mortality of *Chaoborus punctipennis* larvae and pupae exposed for 48 hours to various concentrations of DDT and pyrethrins in tap water. (Each figure represents the average of three duplicate tests.)

Concentration in Water—1 Part in Million	DDT		Pyrethrins	
	Larvae	Pupae	Larvae	Pupae
	Per Cent	*Per Cent*	*Per Cent*	*Per Cent*
30	—	100	—	100
40	—	95	—	100
50	—	90	—	100
75	100	90	100	100
100	98	63	100	100
200	90	30	95	65
400	61	0	88	10
00	52	—	64	—
800	39	—	51	—

It will be noted in table 1 that DDT is almost as toxic as the pyrethrins. DDT was lethal to larvae at 1 part in 75 million parts of water, whereas about twice this concentration was required to kill all pupae. The observation that DDT was lethal to pupae at 1 part in 30 million parts of water suggests that this new compound is an effective contact insecticide against this insect.

With median lethal concentrations of DDT it was observed that 3 or 4 hours elapsed before the larvae became affected, while toxic dosages of pyrethrins produced almost immediate effects. Both materials caused the moribund larvae to rise to the surface.—10-31-44.

[1] This work was conducted under a transfer of funds, recommended by the Committee on Medical Research, between the Office of Scientific Research and Development and the Bureau of Entomology and Plant Quarantine.

[2] Now Captain, Sanitary Corps, Army of the United States.

[3] Reared adults identified by Alan Stone.

Further Tests of Synthetic Organic Compounds as Insecticides

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This paper is the third in a series presenting the results of laboratory tests of the insecticidal effectiveness of synthetic organic compounds at the Sanford, Fla., laboratory of the Bureau of Entomology and Plant Quarantine (Swingle *et al.* 1944a & b). Tests on 45 compounds that were purchased from a commercial manufacturer are reported here. Most of them were of a technical or practical grade, and were not processed to a finely divided particle size as is customary with commercial insecticides. However, they were ground as fine as possible in a mortar before being used, and in most cases a satisfactory dust was obtained.

The tests were made against from five to seven species of leaf-feeding insect pests, most of them larvae of the fourth instar.

The general methods of testing were those described by Swingle *et al.* (1941) and later modified (Swingle 1943), although the screen-cage, foliage-injury, and field-laboratory tests were combined into a single operation, as follows: A 1-per cent spray suspension was applied to five varieties of young truck-crop plants in an outdoor garden. When dry,

Table 1.—Results of insecticide tests of eight synthetic organic compounds when applied as dusts to foliage.

Compound	Insect	Deposit	Mortality after— 2 Days	Mortality after— 3 Days	Feeding on Foliage
		Micrograms per sq. cm.	*Per Cent*	*Per Cent*	
Acetophenone oxime $C_6H_5O(NOH)CH_3$	Bean leaf roller	310	65	81	Slight
	Cross-striped cabbage worm	220	100	—	None
	Hawaiian beet webworm	360	96	100	Slight
	Melon worm	250	92	—	None
	Southern army worm	220	44	92	Slight
1-Acetyl-2-phenylhydrazine $CH_3CONHNHC_6H_5$	Bean leaf roller	215	88	96	Slight
	Cross-striped cabbage worm	180	100	—	Moderate
	Hawaiian beet webworm	255	96	100	Slight
	Melon worm	260	100	—	Slight
	Southern armyworm	180	100	—	None
p-Aminoacetophenone $CH_3COC_6H_4NH_2$	Bean leaf roller	380	33	72	Slight
	Cross-striped cabbage worm	250	88	—	Slight
	Hawaiian beet webworm	265	54	73	Moderate
	Melon worm	540	65	—	Slight
	Southern armyworm	250	21	83	Slight
n-Armyl carbamate $NH_2COOC_5H_{11}$	Bean leaf roller	380	100	—	None
	Cross-striped cabbage worm	250	77	—	Slight
	Hawaiian beet webworm	385	16	40	Moderate
	Melon worm	250	54	—	Slight
	Southern armyworm	250	0	—	Moderate
1-tert-amylurea $C_5H_{11}NHCONH_2$	Bean leaf roller	155	76	96	Slight
	Cross-striped cabbage worm	225	0	—	Much
	Hawaiian beet webworm	210	73	77	Slight
	Melon worm	170	96	—	Slight
	Southern armyworm	225	38	—	Moderate
Aniline hydrobromide $C_6H_5NH_2 \cdot HBr$	Bean leaf roller	325	88	92	None
	Cross-striped cabbage worm	265	96	—	None
	Hawaiian beet webworm	420	100	—	None
	Melon worm	385	100	—	None
	Southern armyworm	265	88	100	Slight
Aniline hydrochloride $C_6H_5NH_2 \cdot HCl$	Bean leaf roller	260	92	96	Slight
	Cross-striped cabbage worm	300	88	—	None
	Hawaiian beet webworm	150	—	68	Moderate
	Melon worm	200	100	—	None
	Southern armyworm	300	—	92	Slight
2, 4-Xylidene acetate $(CH_3)^2C_6H_3NH_2 \cdot CH_2COOH$	Cross-striped cabbage worm	165	92	—	Moderate
	Hawaiian beet webworm	165	4	—	Much
	Melon worm	165	92	—	Slight
	Southern armyworm	165	45	48	Moderate

leaf sections were cut from various plants and fed to insects in petri dishes in the laboratory. After 2, 4, and sometimes 6 days, a record was made of insect mortality and an estimate of the amount of feeding on the leaves. In this manner the effectiveness of the spray deposit as a stomach poison on the date of application was established. On the third and seventh days after spraying, the plants in the garden were examined for foliage injury, and, if none or only slight injury had occurred, leaf sections were again cut from the plants and fed to insects in petri dishes in the laboratory. This test established the toxicity of the deposit after 7 days of weathering (other than rainfall, from which they were protected). On the seventh day, after the leaf sections had been removed from these tests, the plants were resprayed, and 7 days later a final check was made for foliage injury.

Eight of the compounds tested were either toxic or very repellent to at least half of the species against which they were tested. The results of the preliminary petri-dish tests of foliage dusted with these compounds are summarized in table 1:

The results of the other tests with these materials are summarized in the following paragraphs:

Acetophenone oxime.—When a dust deposit on a glass slide was weighed, this compound was found to be too volatile (50 per cent in 2 days) for use as a stomach insecticide on foliage. In fumigation tests in petri dishes the compound was effective against three species of lepidopterous larvae, showing that the results presented in table 1 may have been caused by fumigation.

1-Acetyl-2-phenylhydrazine.—Since this compound was practically nonvolatile in 5 days, it was tested for effectiveness as a stomach insecticide. Excellent results were obtained with a 1 per cent spray suspension against larvae of five species of truck-crop insects, but since the spray severely injured six common varieties of truck crops, the compound is of doubtful value for use on foliage.

p-Aminoacetophenone.—This material was also nonvolatile. When a 1 per cent suspension was tested as a stomach insecticide on foliage, it was effective against two out of four species, but the spray severely injured several varieties of truck-crop plants.

n-Amyl carbamate.—A dust deposit was completely volatile within 2 days, making it unsuitable for use as a stomach insecticide on foliage. The results in table 1 were probably due to fumigation, as the compound was found effective as a fumigant against the cross-striped cabbage worm and the melon worm.

1-tert-Amylurea.—This material was not volatile and was tested as a stomach insecticide against three species. As a 1 per cent spray it was effective against the southern armyworm, but not against the cross-striped cabbage worm and a looper, *Autographa oo* Cram. This spray caused moderate injury to foliage of bean, potato, and swiss chard, slight injury to lettuce, and no injury to broccoli and pumpkin. The compound is not sufficiently toxic to permit the dilution necessary to prevent foliage injury.

Aniline hydrobromide and *aniline hydrochloride.*—These compounds are not volatile, but 1 per cent sprays were not effective when tested as stomach insecticides against five common truck-crop insects. The better results in table 1 must be due to the use of a dust, which means a much heavier dose and the added effect of any possible contact action.

2, 4-Xylidene acetate.—Since this compound was effective against only two of the four insects subjected to the preliminary tests, it might be classed as a rather mediocre insecticide. It was also found to be completely volatile within 2 days.

The remaining 37 compounds, which were found to be either nontoxic or not sufficiently toxic to warrant further testing, are as follows:

Acetanilide
Acetone oxime
Acetone sodium bisulfite
m-Acetamidobenzoic acid
p-Acetaniside
Acetylcholine bromide
Acetyl methylurea
Acetylphenylglycine
1-Acetyl-2-thiohydantoin
Adipamide
3-Amino-1, 5-naphthalenedisulfonic acid
5-Amino-1-naphthalenesulfonic acid
8-Amino-1, 3, 6-naphthalenetrisulfonic acid
2-Amino-4-nitrophenol
o-Aminophenol hydrochloride
2-Amino-1-phenol-4-sulfonic acid
6-Amino-m-toluenesulfonic acid
Ammonium sulfamate
p-tert-Amylphenol
4-p-Anisyl-3-buten-2-one
o-Chloroacetoacetanilide
3, 5-Diiodoanthranilic acid
N, N-Dimethyl-p-phenylenediamine
p-Hydroxyacetanilide
p-Hydroxy-N-methylacetanilide
1, 5-Naphthalenedisulfonic acid
2-Naphthalenesulfonic acid monohydrate
2-Naphthol-6-sulfonic acid
1, 2-Naphthoquinone
2-Naphthoylacetonitrile
2-Naphthyl ester of acetic acid
2-Naphthyl ester of benzoic acid
2-Naphthyl ester of salicyclic acid
2-Naphthylamine hydrochloride
2-Nitro-p-acetaniside
6-Nitro-2,4-acetoxylide
Salicylaldehyde triacetate

SUMMARY.—Of 45 compounds recently tested for insecticidal action against a number of truck-crop insects, 8 materials were found to be toxic. Of these, 3 were volatile and evidently killed by fumigation, 3 were not effective when tried as a stomach-insecticide spray, and the 2 that were effective as stomach poisons, were very injurious to foliage.—7-31-44.

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Toxicity of Diaryl Trichloroethanes and Dichloroethylenes to Codling Moth

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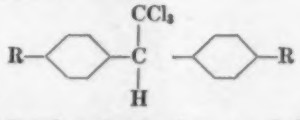
In tests of DDT (2,2-bis(parachlorophenyl)-1,1,1-trichloroethane) against larvae of the codling moth, *Carpocapsa pomonella* (L.), Wiesmann (1943) and Siegler (1944) found that this material was highly effective. It was therefore considered desirable to prepare some related compounds, diaryl trichloroethanes and dichloroethylenes, in order to study the effect of substituents other than chlorine in the benzene rings with respect to toxicity.

The diaryl trichloroethanes tested have the general formula:



in which R is bromine, methoxy, methyl, acetoxy, or hydrogen. These compounds were prepared by the conventional method of condensing 1 mole of chloral hydrate, by weight, and 2 moles of the required aryl compound in the presence of concentrated sulfuric acid (Müller 1943).

The dichloroethylenes tested were prepared from the diaryl trichloroethanes by splitting off hydrogen chloride by means of alcoholic alkali.

Each compound was prepared for its application as a spray by first dissolving it in ethanol (95 per cent), and then precipitating it with water, which was added to make a carrier containing 20 per cent of ethanol by volume. All compounds were used at the rate of 4 pounds to 100 gallons of the carrier.

The toxicity tests were made by the apple-plug method, one ready-to-hatch codling moth egg being used for each plug. With the exception of the test of 2,2-diphenyl-1,1,1-trichloroethane, in which 68 apple plugs were used, 100 or more plugs were employed in each test.

The results are given in table 1. The substitution of bromine for chlorine in the benzene rings of the DDT formula, while still giving a rather toxic compound, caused a decrease in toxicity. The compounds that contained either the methoxy or the methyl substituent in the rings were highly toxic, but the presence of the acetoxy group in the rings totally destroyed toxicity. The compound with no substituents in the rings showed considerable loss in effectiveness.

When hydrogen chloride was split off to give dichloroethylene derivatives, the toxicity of the resulting compounds was very low.

Table 1.—Effectiveness of various diaryl trichloroethanes and dichloroethylenes against codling moth larvae when tested by the apple-plug method.

COMPOUND	FORMULA	PER CENT OF APPLE PLUGS	
		Wormy	Stung
2,2-Bis(p-chlorophenyl)-1,1,1-trichloroethane (DDT)	$(C_6H_4Cl)_2CHCCl_3$	0	0
2,2-Bis (p-bromophenyl)-1,1,1-trichloroethane	$(C_6H_4Br)_2CHCCl_3$	23[1]	17
2,2-Di-p-anisyl-1,1,1-trichloroethane	$(C_6H_4OCH_3)_2CHCCl_3$	3	0
2,2-Di-p-tolyl-1,1,1-trichloroethane	$(C_6H_4CH_3)_2CHCCl_3$	7	2
2,2-Bis(p-acetoxyphenyl)-1,1,1-trichloroethane	$(CH_3COOC_6H_4)_2CHCCl_3$	99	0
2,2-Diphenyl-1,1,1-trichloroethane	$(C_6H_5)_2CHCCl_3$	47	0
2,2-Bis(p-chlorophenyl)-1,1-dichloroethylene	$(C_6H_4Cl)_2C{:}CCl_2$	85	0
2,2-Bis(p-bromophenyl)-1,1-dichloroethylene	$(C_6H_4Br)_2C{:}CCl_2$	86	4
Lead arsenate		40[2]	7
Check (no treatment)		95[3]	0

[1] Average of 2 tests.
[2] Average of 5 tests.
[3] Average of 4 tests.

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Gasoline to Control Green June Beetle Larvae in Tobacco Plant Beds

L. B. SCOTT and JOE MILAM, *U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*

Larvae of the green June beetle, *Cotinis nitida* (L.), often disturb the soil surface of tobacco plant beds, thereby uprooting and destroying many of the tobacco seedlings. Paris green-bran bait is partially effective against the grubs, but serious losses often occur after this treatment has been applied.

The results of preliminary tests in 1941, 1942, and 1943 indicated that gasoline poured into holes 4 to 8 inches deep and 18 inches apart was useful in controlling this pest when applied at the rate of 4 or 5 fluid ounces per hole. The holes, made with an iron bar, were about 2.5 inches in diameter, which is sufficiently large to keep the level of the gasoline at least 2 inches below the soil surface, thus decreasing the danger of injury to the roots of the tobacco

Table 1.—Mortality of green June beetle larvae in soil treated with gasoline. Clarksville, Tenn., 1941, 1942, and 1943.

Year and Plot	Replicates	Area Treated	Depth of Holes	Gasoline per 100 Sq. Yds.	Time to Examination	Depth of Excavation	Larvae Found	Larval Mortality
	Number	*Sq. Yds.*	*Inches*	*Gallons*	*Days*	*Inches*	*Number*	*Per Cent*
1941	2	22	4	12.4	4	12	25	64
1941 (check)	2	22	—	—	4	12	37	0
1942 No. 1	3	16	5	15.6	4	12	96	68
1942 (check)	3	16	—	—	4	12	60	2
1942 No. 2	3	16	5	12.4	4	12	94	85
1042 (check)	3	16	—	—	4	12	60	2
1943	6	33	8	15.6	5	14	80	66
1943 (check)	6	33	—	—	5	14	58	0

seedlings. The holes were plugged with lumps of moist soil after the gasoline was applied.

The experiments of 1941 and 1942 were conducted in a soil composed of clay covered with approximately 3 inches of leafmold. Two experiments conducted in 1943 were in a similar soil and also in sandy loan. The treatment appeared to be more effective in sandy loam than in the other type of soil, although the results were not conclusive. Excessive soil moisture appeared to reduce the effectiveness of the treatment.

To determine the effect of gasoline treatments on larval mortality (Table 1), tests were conducted in areas known to be infested with green June beetle larvae, and in all cases the treatment was applied after surface activity of the grubs was noted. The plots were prepared in accordance with local practice in preparing seed beds, except that the soil was not sterilized and no seed was sown. Practically no surface activity of the larvae occurred after the treatment was applied, apparently indicating that few grubs were alive, but treated plots of fallowed soil were carefully excavated and counts made of the living and dead larvae. Approximately one-third of the larvae were alive, but since only a few came to the soil surface, they probably would not have caused appreciable injury to plants, had plants been present.

To obtain information concerning the effect of gasoline on tobacco seedlings, the treatment was applied each year to one or more uninfested plant beds in which tobacco plants were growing. Direct damage to the tobacco seedlings was avoided by applying the gasoline well below the space occupied by the roots. The liquid evaporated rapidly and had apparently disappeared before the roots reached the treated soil. Only slight damage resulted when gasoline was spilled inadvertently on the seedlings. A slight yellowing of leaves was noted on occasional plants immediately adjacent to points of application, but no plants were killed, and for practical purposes it may be said that no damage resulted.

In 1943, gasoline was applied at the rate of 5 gallons per 100 square yards to a 325-square-yard commercial tobacco plant bed which had been abandoned by the owner because of damage by larvae of the green June beetle. The same procedure was followed as in the experimental beds except that the holes were located in the areas of heaviest infestation instead of being spaced regularly 18 inches apart. No insect damage occurred after the treatment was applied, and the owner pulled a satisfactory crop of plants from the bed. No detectable plant damage resulted from the treatment.—8-26-44.

A Striping of Pineapple Leaves Caused by *Pseudococcus brevipes*[1]

WALTER CARTER

This symptom was first observed in field grown pineapple plants in 1935. A short section on each leaf of 3 or 4 leaves of an inner whorl is characterized by streaks of pale green to yellow and the water storage tissue in the striped area collapses. (Fig. 1)

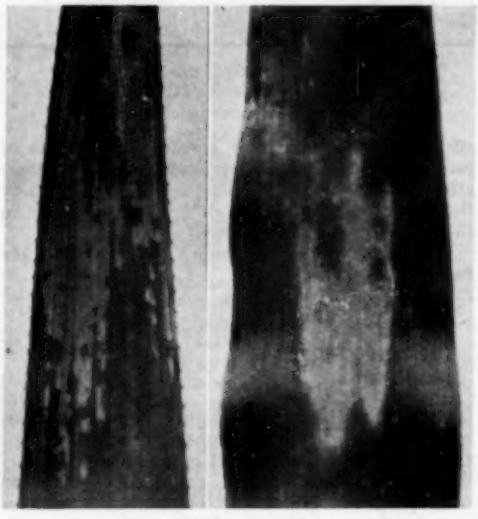

FIG. 1.—A localized stripe symptom caused by the feeding of *Pseudococcus brevipes*.
A. A fresh symptom on upper portion of inner leaf. B. Old symptom showing development of scar tissue.

Affected plants were kept under observation and no new development or extension of the striping occurred.

The association of this symptom with mealybug feeding was indicated as a result of a greenhouse experiment on mealybug wilt. Pineapple plants were

[1] Published with the approval of the Acting Director as Technical Paper No. 156 of the Pineapple Research Institute of Hawaii, University of Hawaii.

Table 1.—Mealybug stripe experiments. Results of successive transfers of mealybug colonies to seedlings or Cayenne plants from stump sections.

SOURCE OF COLONY	TRANSFER 1	RESULTS	SOURCE OF COLONY	TRANSFER 1A	RESULTS
Mealybugs fed on stripe leaf	6 seedlings	3 negative 3 positive	Mealybugs fed on stripe leaf	5 cayenne	All negative
	Transfer 2			*Transfer 2a*	
Seedling series from Transfer 1			Negative plants from cayenne series	5 seedlings	Negative
Positive cases	3 seedlings	Negative			
Negative cases	3 seedlings	Negative			
	Transfer 3			*Transfer 3a*	
Negative cases from Transfer 2	17 cayenne	Negative	Negative cases from Transfer 2a	9 seedlings	3 positive. Al mealybugs from same seedling
	Transfer 4			*Transfer 4a*	
Negative cases from Transfer 3	20 seedlings	1 positive	Positive cases from Transfer 3a	3 seedlings 3 seedlings 3 seedlings	1 positive 3 positive 3 positive
			Negative cases from Transfer 3a	18 seedlings	All negative
			Single bugs from positive 3a	36 seedlings	3 positive after colonies developed
			Mass colonies from positive 3a	6 seedlings	All negative

grown in soil in cans and some were infested with mealybugs. No wilt occurred but some of the infested plants showed the typical stripe symptom, which was entirely absent from the uninfested checks. Since then, the symptom has been frequently observed in field plots where infestations of mealybugs have been made and the striped areas are invariably found in the zone on the leaf where the mealybug feeding occurred. No extension beyond this localized area has ever been observed.

Affected plants kept under observation until fruiting time showed no other effect on the plant and the progenies of these plants showed no symptoms either before removal from the mother plant or during the following 20 months of plant crop growth. Feeding by both the green spotting and the non-green spotting strains of *P. brevipes* has produced the symptoms. The results of laboratory tests are shown in table 1, from which it is clear that Cayenne plants grown from stump sections failed to develop the symptoms and that the irregularity of appearance of the symptom on hybrid seedlings indicates that the reaction is relatively rare. The standard commercial Cayenne variety rarely if ever shows striping but it is seen fairly frequently on a local sub-variety known as Hilo and on hybrid seedlings, when these are artificially infested with large mealybug colonies.

The symptom is interpreted as non-systemic but affecting a local area rather than actual feeding points and as a specific plant reaction to the complex insect secretion different from the two types of spotting and the systematic mealybug wilt.—7-19-44.

New Mosquito Distribution Records from the Seventh Service Command Area

THEODORE A. OLSON, Major, SnC and HUGH L. KEEGAN, 1st Lt., SnC,[1] *7th Service Command Medical Laboratory*

Following are 36 new state mosquito distribution records, obtained through the Army mosquito collecting program during 1942, 1943 and 1944, in the nine state area of the 7th Service Command. States included in the Service Command Area are: Colorado, Iowa, Kansas, Minnesota, Missouri, Nebraska, North Dakota, South Dakota, and Wyoming. Unless otherwise indicated, collecting dates given are for 1944.

Colorado

1. *Anopheles maculipennis occidentalis* Dyar and Knab
   Adult records: Fort Logan: August (1)
2. *Anopheles punctipennis* (Say)
   Larval records: Pueblo AAF: June (23)
3. *Culex apicalis* Adams
   Adult records: Fort Logan: August (12)
4. *Culex salinarius* Coquillett
   Adult records: Camp Carson: June (29); Fort Logan: August (22)
5. *Psorophora confinnis* (Lynch & Arribalzaga)
   Adult records: Lowry Field (Denver): July (17)

[1] The writers greatly appreciate the technical assistance of Mrs. Ruth Pegau and Miss Hilda Jean May.

6. *Theobaldia melanura* (Coquillett)
Adult records: Fitzsimons General Hospital (Denver): July (14, 16, 31)
7. *Theobaldia morsitans* Theobald
Adult records: Fitzsimons General Hospital (Denver); May (30), July (6), August (6, 14); Trinidad POW Camp: July (11)

Iowa

1. *Culex quinquefasciatus* Say
Adult records: Clarinda POW Camp: July (12, 13); Sioux City AAB: July (25)
2. *Psorophora discolor* (Coquillett)
Adult records: Clarinda POW Camp: August (8)
3. *Theobaldia melanura* (Coquillett)
Adult records: Camp Dodge: June (8)

Kansas

1. *Aëdes dorsalis* (Meigen)
Adult records: Camp Phillips (Salina): June (20), August (1); Fort Riley: July (22), August (4)
2. *Aëdes flavescens* (Muller)
Adult records: Camp Phillips (Salina): June (11) 1943
3. *Aëdes sticticus* (Meigen)
Adult records: Concordia POW Camp: May (22); Fort Leavenworth: May–August; Fort Riley: June (8, 9, 15); Winter General Hospital (Topeka): May (14, 16, 18)
Larval records: Concordia POW Camp: May (22); Fort Leavenworth: May (5, 6, 29), July (10)
4. *Aëdes trivittatus* (Coquillett)
Adult records: Fort Leavenworth: May (22), June (24), July (2, 3, 7, 11, 14, 18, 29); Camp Phillips (Salina): June (27); Fort Riley: June (8, 9, 15, 28), July (1, 10, 11, 28), August (4); Winter General Hospital (Topeka): May (21, 23)
5. *Culex erraticus* Dyar and Knab
Adult records: Fort Leavenworth: July (11, 15, 17, 25, 27, 28); Camp Phillips (Salina): July (19); Winter General Hospital (Topeka): August (17)
Larval records: Fort Leavenworth: June (22)
6. *Culex peccator* Dyar and Knab
Adult records: Fort Leavenworth: July (24) 1944, September (19) 1942, November (6) 1942
7. *Culex salinarius* Coquillett
Adult records: Concordia POW Camp: June (1, 23, 29), July (5); Fort Leavenworth: May–Ausust; Camp Phillips (Salina): May–August; Fort Riley: May–August; Winter General Hospital (Topeka): May (23)
Larval records: Concordia POW Camp: June (1, 29), July (5); Fort Leavenworth: June (14); Fort Riley: May (25), June (30)
8. *Mansonia perturbans* (Walker)
Adult records: Winter General Hospital (Topeka): August (25); Fort Leavenworth: September (5) 1943, September (4) 1944
9. *Orthopodomyia alba* Baker
Adult records: Fort Leavenworth: May (27), June (2); Fort Riley: July (22, 24), August (4, 12); Camp Phillips (Salina): August (21) 1943
10. *Orthopodomyia signifera* (Coquillett)
Adult records: Fort Leavenworth: June (16) 1943; Fort Leavenworth: August (3, 5, 6, 9, 13, 14, 19, 23, 26) 1944
11. *Psorophora discolor* (Coquillett)
Adult records: Fort Leavenworth: June (26, 29, 30), July (3, 7, 8, 11, 27), August (5, 14, 21); Camp Phillips: July (20, 26, 29); August (3, 12); Fort Riley: July (11, 22, 28), August (12, 17); Winter General Hospital (Topeka): August (17)
12. *Psorophora ferox* (Humboldt)
Adult records: Fort Leavenworth: June (17), August (14); Camp Phillips (Salina): July (11)
Larval records: Fort Leavenworth: June (13, 19)
13. *Psorphora howardii* (Coquillett)
Adult records: Camp Phillips (Salina): June (24) 1943
14. *Uranotaenia sapphirina* (Osten Sacken)
Adult records: Fort Leavenworth: July (8, 14, 17, 22), August (8, 9, 14); Fort Riley: July (11, 24), August (9, 12); Winter General Hospital (Topeka): October (21) 1943

Missouri

1. *Aëdes dorsalis* (Meigen)
Adult records: Camp Crowder: August (10); Jefferson Barracks: May (22) 1942, June (29) 1942, July (1, 2, 21) 1942, September (12) 1942
2. *Aëdes dupreei* (Coquillett)
Adult records: Camp Crowder: June (12); Jefferson Barracks: May (31)
3. *Aëdes infirmatus* Dyar and Knab
Larval records: Camp Crowder: May (15)
4. *Aëdes atropalpus* (Coquillett)
Adult records: Camp Crowder: September (4)
Larval records: Camp Crowder: September (2)
5. *Anopheles pseudopunctipennis*, Theobald
Adult records: Camp Crowder, October (2)

Nebraska

1. *Aëdes fitchii* (Felt & Young)
Adult records: Fort Robinson: May (20), June (24)
2. *Aëdes sollicitans* (Walker)
Adult records: Lincoln: July (7); Fort Omaha: June (5), July (7, 9, 10), August (2, 7) 1942
3. *Psorophora discolor* (Coquillett)
Adult records: Alliance AAF: July (7); Atlanta POW Camp: June (6, 20, 24), August (5); Lincoln AAF: June (22, 23), July (7, 8, 11); Fort Omaha: June (2); Fort Robinson: July (29)
4. *Psorophora horrida* (Dyar & Knab)
Adult records: Fort Omaha: July (3, 4, 8, 16)
5. *Theobaldia melanura* (Coquillett)
Adult records: Fort Robinson: August (11, 19)

South Dakota

1. *Anopheles quadrimaculatus* Say
Adult records: Watertown AAF: August (18)

Wyoming

1. *Anopheles punctipennis* (Say)
Adult records: Ft. Francis E. Warren: August (23)

—9-27-44.

"Entomology Unit" in the Corps of Engineers

CAPT. W. D. REED, *Army Service Forces, Office of the Chief of Engineers, Washington, D. C.*

Since early in 1943 the Corps of Engineers has taken on an increasing responsibility for the supervision and execution of Control Measures for Insect, Rodents, and other Vermin, in cooperation with the Army Medical Department. An account of the work is given in JOURNAL OF ECONOMIC ENTOMOLOGY, Vol. 37, No. 3, pp. 333–5, June 1944.

The following is a list of Entomologists appointed by the Corps of Engineers to have charge of the work:

Office of the Chief of Engineers, Repairs and Utilities Branch, Washington, D. C.

Capt. W. D. Reed, in charge, Insect and Rodent Control Unit. Before enlisting in the Army, Capt. Reed was employed by the Bureau of Entomology and Plant Quarantine with Headquarters at Richmond, Virginia.

Headquarters, First Service Command, ASF, Office of the Service Command Engineers, 808 Commonwealth Avenue, Boston, 15, Massachusetts.

Mr. John M. LeCato, Entomologist, in charge Insect and Rodent Control. Mr. LeCato was formerly employed as Sanitarian with the U. S. Public Health Service with Headquarters at Fayetteville, North Carolina.

Headquarters, Second Service Command, ASF, Office of the Service Command Engineer, 270 Broadway, New York, 7, New York.

Mr. Kent Littig, Entomologist, in charge, Insect and Rodent Control.

Headquarters, Third Service Command, ASF, Office of the Service Command Engineer, 101 East Fayette Street, Baltimore, 2, Maryland.

Mr. S. S. Easter, Entomologist, in charge, Insect and Rodent Control. Mr. Easter was formerly employed by the Bureau of Entomology and Plant Quarantine, with Headquarters at New Orleans, La.

Headquarters, Fourth Service Command, ASF, Office of the Service Command Engineer, 618 Hickey Building (P.O. Box 4114), Atlanta, 2, Georgia.

Mr. Austin W. Morrill Jr., Entomologist, in charge, Insect and Rodent Control. Mr. Morrill was formerly employed by the Bureau of Entomology and Plant Quarantine, with Headquarters at Beltsville, Maryland.

Headquarters, Fifth Service Command, ASF, Office of the Service Command Engineer, Fort Hayes, Columbus, 18, Ohio.

Lt. Lee C. Truman, in charge, Insect and Rodent Control. Before accepting a Commission in the Army, Lt. Truman was Professor of Entomology at the University of Pittsburgh.

Headquarters, Sixth Service Command, ASF, Office of the Service Command Engineer, 20 North Wacker Drive, Chicago, 6, Illinois.

Dr. E. M. Searls, Entomologist, in charge, Insect and Rodent Control. Dr. Searle was formally employed by the University of Wisconsin, and the Wisconsin Agricultural Experiment Station, Madison, Wisconsin.

Headquarters, Seventh Service Command, ASF, Office of the Service Command Engineer, Federal Building, 15th and Dodge Streets, Omaha, 2, Nebraska.

Mr. Don B. Whelan, Entomologist, in charge, Insect and Rodent Control. Mr. Whelan was formerly employed by the University of Nebraska, and the Nebraska Agricultural Experiment Station, Lincoln, Nebraska.

Headquarters, Eighth Service Command, ASF, Office of the Service Command Engineer, Santa Fe Building, Dallas, 2, Texas.

Mr. Charles L. Smith, Entomologist, in charge, Insect and Rodent Control. Mr. Smith was formerly employed by the Bureau of Entomology and Plant Quarantine, with Headquarters at Menard, Texas.

Headquarters, Ninth Service Command, ASF, Office of the Service Command Engineer, Fort Douglas, Utah.

Dr. George F. Knowlton, Entomologist, in charge, Insect and Rodent Control. Dr. Knowlton was formerly employed by the Utah Agricultural Experiment Station, Logan, Utah.—9-7-44.

DDT for "Out of Place" Honeybee Colonies

D. O. WOLFENBARGER, *Delaware Agricultural Experiment Station, Newark*

Honeybee colonies often abide in houses or other structures frequented by humans from which they sometimes emerge and sting, or at least make themselves unwanted because of fear that they might sting. Bees in such locations may be considered "out of place" and their removal or eradication deemed necessary. Their removal may be effected by (1) transferring brood and comb or, (2) by using the funnel or escape method, outlined by Sechrist (1932). Eradication is often accomplished by fumigation, closure of colony confines, burning, drenching, mechanical processes, or a combination of methods. Fumigation of undesirable colonies is most frequently practiced. Materials commonly used for fumigation are sulfur, calcium cyanide, carbon disulphide. There are advantages and disadvantages in the use of each of these materials. The material selected may depend on the situations involved.

An organic insecticide recently brought into use, commonly called DDT, gives much promise as an eradicant for honeybee colonies "out of place." It was shown by Holst (1944) to be toxic to bees.

Attention was called to one colony located apparently under the roof or in the eaves of a large two-story house, which was practically given up as a hopeless case for eradication because of the difficulties presented by three entrances, a long lead-in tunnel, and an inability to locate the brood nest. Attempts to kill the bees with carbon disulphide and with powdered calcium cyanide had been unsuccessful.

An eradication procedure was employed in which a small, plunger-type hand duster charged with *Gesarol A-20 Spray* (20% DDT) was used to blow the dust particles into the entrances of the colony. A total of about five ounces of the material was

dispersed into the entrance. This amount was sufficient to coat the tunnels and entrances and emerge in visible amounts from those not being treated, on each of three applications. Fewer applications might have been sufficient.

A week after the first application, the honeybees about the entrance were fewer in number and two weeks afterward only one recently emerged malformed bee appeared in response to another application of dust. A few faint sounds of a very weak and hopelessly queenless colony were audible. Three weeks later two recently emerged bees were observed, and no audible response to pounding on the house was detectable. Furthermore, there was an odor of dead brood, suggestive of a dead colony. This colony is, therefore, considered eradicated.

Advantages of the material used are (1) continued residual action to the honeybees, (2) absence of fire-hazard, (3) safety to occupants of the house, (4) ease, thoroughness, and safety of application. The cost of the material, when it becomes available should be reasonable.—8-8-44.

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The Theory of Probits at High Mortalities

DONALD F. STARR, *U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*

Since the presentation of probits (Bliss 1935) for transforming mortality data from a symmetrical sigmoid curve to a straight line, many insect toxicologists have applied the transformation to the analysis of their results. A majority of the dosage-mortality or time-mortality curves from the action of a toxicant have been linear or made up of two linear segments when the time or dosage units have been transformed to logarithms.

In spite of the repeated application of the probit-log transformation at mortalities from about 30 to 99 per cent, occasionally there has been evidence of hesitation in applying the same relationship to higher mortalities. As opposed to this attitude of hesitation, Baker (1939) recommended a security corresponding to a probit of 9, or a mortality of 99.99683 per cent. Since there is no probit value corresponding to 100 per cent mortality, some may have reasoned that extrapolation of the dosage mortality curve must fail to reach 100 per cent, or complete mortality, at any finite degree of treatment. However, there are many well known examples of conditions under which a species either of plants or animals cannot possibly exist. With these two discordant facts available it may have appeared that a strict application of a linear probit-log relationship led to an absurdity, namely, that complete mortality of a species could occur only if it were subjected to an infinite treatment. The strict interpretation of the linear probit-log relationship requires an infinite treatment for complete mortality *only if there is an infinite number of individuals to be killed.*

Table 1.—Percentages of mortality and expected survivals corresponding to probits from 9 to 20.

PROBIT	PER CENT	SURVIVORS
9	99.99 683	3 out of 10^5
10	99.999 971	3 out of 10^7
11	99.9_6... 901	1 out of 10^9
12	99.9_9... 872	1 out of 10^{12}
13	99.9_{12}... 938	6 out of 10^{14}
14	99.9_{15}... 989	1 out of 10^{19}
15	99.9_{21}... 238	8 out of 10^{24}
16	99.9_{24}... 981	2 out of 10^{28}
17	99.9_{28}... 822	2 out of 10^{33}
18	99.9_{34}... 388	6 out of 10^{39}
19	99.9_{42}... 221	8 out of 10^{46}
20	99.9_{48}... 633	4 out of 10^{51}

In order to clarify the above statement a table of higher probits was calculated from Pearson's Table IV (1924). The data in table 1 will be of little value in preparing mortality curves but they provide arithmetical evidence regarding the theory of probits at high mortalities.

With table 1, the probit corresponding to something less than one survivor out of any species can be estimated if an approximation of the total number of individuals is available. As an example, suppose a ridiculous overestimate of the number of houseflies is made. If the entire land area of the world, which is estimated as over 56 million square miles, were covered with houseflies at the rate of 25 per square inch the total would be 5.6×10^{13}. The complete mortality of such a number could be expected at a probit close to 14. Some recent data on the toxicity of pyrethrum extract to houseflies (Wadley & Sullivan 1943), with a straight line fitted to the mortality points above 20 per cent, could be extrapolated to a probit of 14 at a concentration of 5.8 g. per 100 cc. This concentration, estimated to exterminate a species completely is much less than an infinite dosage even though it is several times as great as would be required for practical purposes.

The above example is offered only as an indication that the rigid application of the probit system does not lead to hypothetical impossibilities at the high mortalities. The toxicologist may apply the probit transformation without the reservation that the linear relationship must fail at some high mortality. Examples that are already available and those that will be found in the future which do not fit a straight line do not necessarily disprove the usefulness of probits. Instead, the lack of linearity in a mortality curve might better be accepted as a clue to some difference in the mode of toxic action.—8-23-44.

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Variations in the Susceptibility of California Red Scale to Oil Sprays

A. W. CRESSMAN, *U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*

In experimental work with the California red scale, *Aonidiella aurantii* (Mask.), large differences in susceptibility of the scale to oil sprays have been observed. In laboratory tests in a settling-mist chamber, in which the scales were collected from different groves and brought to the laboratory for treatment at different times, mortalities of mature scales treated with light-medium oil have ranged from 87 per cent with an oil deposit of 126 micromilliliters per square centimeter to 11 per cent with a deposit of 115 micromilliliters, or 45 per cent with a deposit of 151 micromilliliters. In field experiments, mortalities were 16 per cent in one grove and 95 per cent in another with an oil deposit of 109 micromilliliters per square centimeter in each grove. In order to determine whether such differences were inherent in scales from different sources, stocks from four orchards were reared under identical conditions in the laboratory and after several generations were tested for comparative susceptibility to oils. Stocks A and C were taken from the groves showing the highest and lowest mortalities from field sprays, stock B from a grove where mortalities from field sprays had been between these two extremes, and stock D from the grove that yielded the highest mortality in the laboratory tests. After the first test the pure strains of stocks A and B were lost, but a mixture of the two stocks was continued.

Sprays were applied when the scales were mature, according to the method described by Cressman (1943). Equal numbers of each stock under test were placed on each rack snd sprayed with a light-medium oil. The data are given in table 1.

Table 1.—Results of laboratory tests of susceptibility of different stocks of the California red scale to oil sprays.

Concentration of Oil (Per Cent)	Mortality of Stocks in Per Cent				
	A	B	C	D	AB
Sprayed May 15, 1943					
0.75	53.4	43.6			
1.25	77.0	68.8			
Sprayed September 14, 1943					
.75				83.9	82.4
1.25				90.5	91.5
Sprayed February 22, 1944					
1.25			31.9	31.5	31.5
.75+1.50			72.7	77.4	74.8

After the sprays applied in February 1944, inspection indicated very little kill of the scales treated with an oil of 0.75 per cent concentration, and they were resprayed with one of 1.5 per cent concentration.

The difference between stocks A and B in the mortality from sprays applied in May was probably significant ($P=0.05$) but the difference was small, compared with the differences found in field experiments. No differences were found in the other tests. Although the results of the first sprays suggest the existence of small differences in inherent susceptibility to oils, it is evident that the larger part of the differences in mortality observed after field sprays, or after laboratory sprays applied to scales collected in the field, cannot be explained by genetic differences in susceptibility.

In the laboratory tests reported in table 1, mortalities were much higher in September than in February. This difference was associated with a difference in conditions of the lemons. The fruit treated in September had shown a tendency to dry and shrink during the course of rearing. Lemons for the February sprays were collected from another grove and remained in excellent condition.

In another laboratory test in February 1944 there was no difference between the mortalities of scales 48 and 61 days old. Stocks C, D, and AB were also treated with oil plus derris resins. No difference in mortality was found.

SUMMARY.—Large differences have been found in mortalities of scales sprayed in the field with comparable dosages of oil, or collected in the field and sprayed in the laboratory. Experiments have indicated that little or no part of these differences is due to hereditary factors.—9-5-44.

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The Effect of the Release of Liquid HCN on Temperature Under a Fumigation Tent

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In commercial citrus fumigation the amount of liquid hydrocyanic acid used ranges from 18 to 24 milliliters per 100 cubic feet, depending on the time of year and the susceptibility of the trees and fruit. On the basis of a 24-milliliter dosage per 100 cubic feet, this amount of liquid would theoretically produce a drop of 8.1 Fahrenheit degrees in the air temperature within the tent at the time of the release. Because temperature changes (Quayle & Rohrbaugh 1934, Yust *et al.* 1942) influence the kill of the California red scale, *Aonidiella aurantii* (Mask.), temperatures were determined at several locations within a fumigation tent to measure the decrease caused by the rapid evaporation of the fumigant.

During a series of experimental fumigations, several temperature recordings were made with thermocouples placed inside and outside a duck tent. A dosage of 24 milliliters of liquid hydrocyanic acid per 100 cubic feet was used, and the gas was released under the tent with a blower atomizer (Fulton *et al.* 1941) developed to produce uniform distribution of the fumigant. The temperatures within 12 inches of the blower varied considerably because of the intermittent action of the liquid hydrocyanic acid pump, but all temperatures recorded when the liquid was being atomized were below 32° F. During three fumigations decreases in temperature of 1.0°, 1.0°, and 1.8° were detected within the tent.

On another night three thermocouples were placed within the tent at several locations. One (Fig. 1, *1*)

was placed in the air stream of the blower approximately 7 feet from the nozzles; one (Fig. 1, *2*) was placed near the tent wall on the opposite side from where the hydrocyanic acid was introduced, and hence approximately 15 feet from the blower; and the third (Fig. 1, *3*) was placed equidistant from the center of the tree and the wall of the tent. The thermocouples were placed thus to show the temperature of the blower stream and the decrease in temperature of the air within the tent. A fourth thermocouple (Fig. 1, *4*) was placed outside the tent approximately 6 feet from the ground to determine the air temperature. The results of the release under a duck tent using a dosage of 20 milliliters per 100 cubic feet are shown in figure 1.

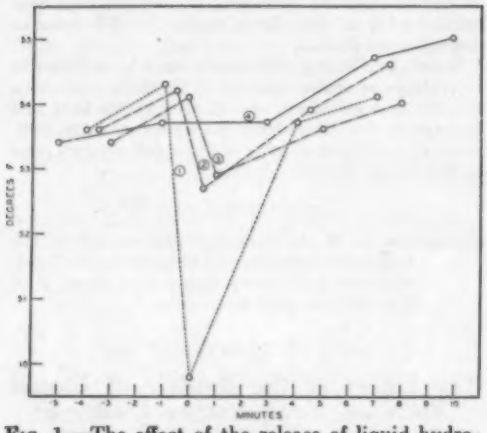

FIG. 1.—The effect of the release of liquid hydrocyanic acid on the temperature under a duck fumigation tent.

The air stream of the blower was cooled 4.5° F. and the air at the other points within the tent showed a decrease of 1.5°.

Thermocouples were also placed in a gastight tent. Using a dosage of 7 milliliters per 100 cubic feet a decrease of 0.5° F. was detected within the tent.

The cooling effect produced by the rapid evaporation of the hydrocyanic acid was not sufficient to influence the kill of the California red scale. Obstructions such as limbs and leaves directly in front of the atomizer (12 to 18 inches) will cause condensation and formation of solid hydrocyanic acid. The formation of solid hydrocyanic acid will reduce the concentration as much as 25 per cent. The reduction in concentration will lower the kill of scale insects. The fog (Fulton & Busbey 1944) produced by the rapid evaporation of the fumigant has no effect on the concentration.

SUMMARY.—The cooling effect of the rapid evaporation of liquid hydrocyanic acid (24 ml. per 100 cubic feet) produced decreases in temperature within a duck fumigation tent of 1.0, 1.0, and 1.8 Fahrenheit degrees in three fumigations. In another experiment, in which a dosage of 20 milliliters per 100 cubic feet was used, a decrease of 1.5 degrees was detected throughout the tent. In a gastight tent using a dosage of 7 milliliters per 100 cubic feet, a decrease of 0.5 degree was detected. This cooling effect is not sufficient to influence the kill of the California red scale. Care must be taken during the introduction of hydrocyanic acid by the blower applicator because surfaces such as limbs and leaves collect liquid hydrocyanic acid, and by continuous evaporation will form solid hydrocyanic acid, thus reducing the initial concentration.

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Cocooning Habits of Spring-Brood Larvae of the Pecan Nut Casebearer

W. C. PIERCE, *U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*

Published literature indicates that the spring-brood larvae of the pecan nut casebearer (*Acrobasis caryae* Grote) remain in their burrows within succulent pecan shoots to form their flimsy cocoons and transform to pupae. This writer, however, has found it extremely difficult to collect a significant number of the spring-brood pupae of this insect within pecan shoots previously tunneled by the larvae, except under conditions of very severe infestation. Detailed observations on this point, incidental to other work, were therefore made near Brownwood, Texas, during the spring of 1944 in orchards having moderate to severe infestations.

The first pupa of this insect taken in these observations was found in a pecan shoot on April 19. Early in the period when pupae were first being formed, April 19–26, no difficulty was experienced in collecting 660 nut casebearer larvae within tunneled pecan shoots in 4 pecan orchards within a 30-mile radius of Brownwood. Only 4 pupae, however, were found within tunneled pecan shoots during that period. From April 28 to May 16 a total of 762 pecan shoots tunneled by the larvae of this insect were collected in 3 orchards in attempts to obtain pupae within the shoots. Thirty-two pupae were found, and the contents of the other larval burrows comprised 31 live larvae, 40 dead larvae, and 66 parasites of this host. The remaining 593 burrows were empty.

During May 1944 approximately 50 cocoons of the nut casebearer were collected in crevices of the bark and under scales of rough bark on pecan trees in orchards near Brownwood. The cocoons of this insect were also observed attached to pecan shoots of the preceding year's growth, at the bases of the shoots and catkins of the current season's growth, on large branches, in pruning scars, and in depressions formed by decay of small lateral branches. The larvae and pupae taken within the cocoons were

heavily parasitized, and some had been destroyed by predators. Approximately 25 nut casebearer moths were reared from the immature stages taken within cocoons in crevices of the bark and under scales of rough bark on trees of the variety Success. Single specimens of two other pecan-attacking species, *Gretchena bolliana* Sling. and *Dichomeris ventrellus* Fitch,[1] were also reared from immature stages collected under scales of rough bark on the tree.

These observations show that a portion of the spring-brood larvae of the pecan nut case bearer migrate from the new growth on which they have fed and form cocoons in various places on other parts of the tree before transforming to pupae. The extent of larval migration and the abundance of the cocoons in different locations on the tree may vary on different varieties of pecan. On 12-year-old pecan trees of the variety Success the cocoons appeared to be as abundant under scales of rough bark in crotches of large branches as on any other part of the trees.

The fact that many larvae of the spring brood leave their tunnels to cocoon in various sheltered places suggests the possibility of trapping them in the corrugated bands used with other insects having similar habits.—10-16-44.

[1] Identifications made by Carl Heinrich of the Division of Insect Identification.

The Distribution of a Bromine Homologue of DDT in Insect Tissue

E. LINDSAY HANSEN,[1] JAMES W. HANSEN, and RODERICK CRAIG, *University of California, Berkeley*

The recent discovery of the effectiveness of dichlorodiphenyltrichloroethane, "DDT," as a contact insecticide has led to speculation about its mode of action. Since it is effective in minute amounts, its course within the insect body cannot be traced by ordinary chemical methods. Radioactive tracer elements, however, offer a means of approach.

There are no readily usable radioactive isotopes of chlorine and carbon. Bromine, however, has a radioactive isotope, Br^{82}, which has a half life of 34 hours and emits beta and gamma radiation. Dibromdiphenyltrichloroethane, except for a slightly lower toxicity, behaves similarly to DDT.

The synthesis was carried out with 5 milligrams of the radioactive bromine[2] through brombenzene to the desired compound. Identity and purity of the material was checked by its melting point, (139.0–0.5 as compared with 140° for the pure compound).

Adult roaches, *Periplaneta americana*, and larvae of the following insects, *Tenebrioides mauritanicus* L., *Tenebrio molitor* L., and *Galleria mellonella* L. were used. A saturated solution of the compound in cellosolve was applied to the posterior thoracic tergites. About 5 c.mm. (0.2–0.3 mg.) was used on the larvae, and 60 c.mm. (about 3.6 mg.) was used on the cockroaches. This was applied over a period of 8 hours. Within 24 hours all the insects were very torpid or dead. They were washed in alcohol to remove the compound from the surface, and were dissected under dilute formalin. Portions of the organs, including the brain and nerve cord, alimentary canal, fat bodies, malpighian tubules, reproductive organs, mouth parts, sternites, cerci, and blood were spread on slides, dried and covered with a celloidon film. These were exposed to X-ray film for a period of 250 to 360 hours.

The radioautographs so obtained were distinct and well exposed. Almost all the tissues could be identified on the exposed film. There is definite evidence that the material was present in the nerve cord and brain as well as in other parts of the insect. It is proposed to continue this investigation using sectioned material to identify the location of the insecticide more accurately.—10-16-44.

[1] Now with Division of Pharmacology, U. C. Medical Center, San Francisco

[2] The radiobromine was obtained through the kind cooperation of Dr. Hamilton of the Radiation Laboratory.

Rate of Evaporation of DDT

ELMER E. FLECK, *U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*

The rate at which DDT will evaporate from a dusted surface was determined by means of a constant-temperature air bath as described by Nelson & Smith (1942), except that a 4-inch glass tube was used. A glass plate 5 by 10 cm. was dusted with DDT from a 325-mesh sieve until a total of 63.36 mg. had been deposited. This plate was then placed in the center of the air bath. The temperature of the bath was maintained at 45° C., and air was passed through it at the rate of about 10 liters per hour. At 4-day intervals the dusted plate was removed from the air bath and weighed to determine the loss of DDT. At the end of 37 days 4.22 mg. had evaporated.

The average evaporation rate of 0.11 mg. per day might be taken to indicate a life of about 18 months. That such a conclusion is not entirely valid is indicated by a change in the rate of evaporation during the 37-day period. Thus, for the first 4 days the rate was 0.34 mg. per day and then decreased regularly for the subsequent 4-day periods, until it was only 0.05 mg. per day. This decrease is believed to be due to a reduction in the surface area of the dusted particles.

The velocity of the air through the air bath was shown not to be a factor. The rate of air flow was varied from 5 liters to 20 liters per hour without any corresponding change in the rate of evaporation of DDT being detected.

The DDT used in these experiments was obtained from commercial material by two recrystallizations from alcohol and subsequent drying in vacuum at room temperature. The purified product melted at 107–8° C.

At the end of the 37-day exposure the DDT was scraped from the plate. The melting point of this material was found to be identical with that of the starting material.

It is concluded that the loss of DDT from insecticidal spray deposits by volatilization will occur too slowly to be of any importance.—9-28-44.

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Wholesale Prices of Insecticides During World Wars I and II[1]

E. R. DE ONG and M. D. LEONARD

The fluctuations of insecticide prices present a marked contrast between the first world war period (1914–1918) and the second world war period (1939–1943). Many of the basic ingredients of insecticides, such as white arsenic and metallic lead, copper and mercury are also required for war materials, hence disturbances in the chemical and metal markets are reflected in the cost of insecticides, Exceptions are noted for specific materials such as the drugs strychnine and calomel. The price of the former is influenced, in the first period, by the disturbance of world shipping conditions and perhaps also by speculative manipulation. Calomel, used in the control of root maggots, follows the price of metallic mercury, which is materially influenced by the sharp demand for fulminating compounds to be used with explosives. Rising prices, allocation of supplies and restricted consumption were the common correctives for shortages in the first war period.

Twelve commodities have been chosen, as representative insecticides or ingredients of insecticides and which have price histories in both war periods. Excepting pyrethrum, these materials were sufficiently consistent throughout the two periods, both in grading and terminology, as to be comparable. A number of common insecticides, including nicotine, rotenone and refined oil emulsions are omitted because quotations were unavailable for the first war period. White arsenic is included as a basic ingredient for the manufacture and standardization of many arsenical compounds and litharge (lead oxide) as a basic form of lead used in the manufacture of certain arsenical compounds.

Production data are not included in the study because of the interrelation of insecticides with other branches of the chemical industry. They are usually a specialty, making up but a fraction of the total factory output (*e.g.* lead arsenate) or furnish a limited market for a widely used commodity such as sulfur. Because of these interrelationships with other chemicals it is impractical, in a limited study, to establish an index of production costs.

This discussion covers: first, the total range of price fluctuations for the first and second periods respectively (Fig. 1); second, the total spread in prices for the two periods, using the prices of January, 1939 as the index, and also the net increase from beginning to end of the two periods (Fig. 2).

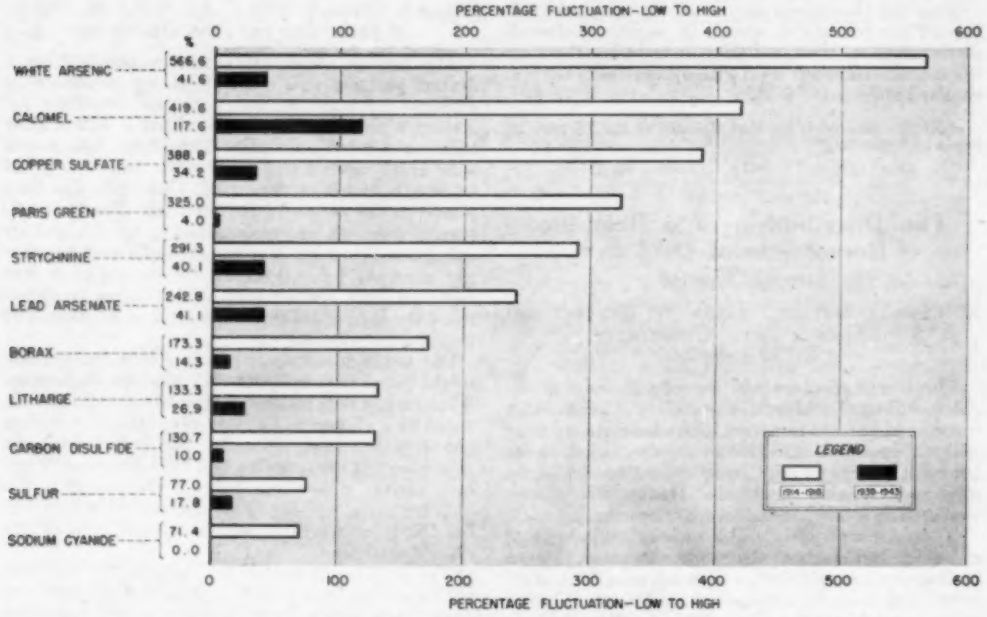

FIG. 1.—Range of price fluctuation of insecticides in World War I and II. (Source: Percentages are based on prices in the *Oil, Paint and Drug Reporter*.)

DISCUSSION OF CHART 1—WARS I AND II: The range of price fluctuation, as illustrated in Chart 1 (Fig. 1) is obtained by using the lowest occurring commodity price in each 5-year period as the base line. The length of the column indicates the percentage rise of the commodity that occurs during the same 5-year period. The figures at the base of the white column are the highest percentage rise of price for that particular period. For example, the range in price of lead arsenate,[2] is the first period, is from $0.105 in February, 1914 to $0.36 in May, 1918—an increase of 242.8 per cent.

Price ranges in the second war period are shown, in the same way, by the black columns. The decreases in price range indicate a more stable price condition generally throughout the industry.

[1] From the Pacific Slope Branch Program, 1944.

[2] Prices on lead arsenate have been adjusted to compensate for differences between the paste and powdered forms.

DISCUSSION OF CHART 2—The prices of January, 1939 are used as the base line for Chart 2. (Fig. 2.) Those falling below this figure are expressed as less than 100 per cent. The first date of the lowest price in the 5-year period is shown at the bottom of the column. Correspondingly, the first date at which the highest price occurred is given at the top of the column.

The price per unit of each commodity for January 1, 1939, as used for the base line is: copper sulfate, $0.045 per pound; lead arsenate, $0.11 per pound; pyrethrum, $0.27 per pound; strychnine, $0.50 per ounce; calomel, $1.36 per pound; carbon disulfide, $0.05 per pound.

Net increases during each period are indicated by the black portion of the column. The lowest point of each black column indicates the price of the commodity in January of the first year of each period. The highest point indicates the price in December of the last year of the period. Fluctuations in price above or below the net increase are shown by the white portion of the column. For example, the base line of copper sulfate, which is expressed as 100 per cent, is $0.045, the quotation for the first week in January, 1939. In October, 1941, the price dropped to $0.041, a loss of 9 per cent, which is so indicated on the graph by a white column below the base line, followed by the date of June, 1939. In August, 1941, it raised to $0.055, a gain of 22 per cent over the base figure and dropped to $0.05 in December, 1943, a net gain of 11 per cent.

The commodities illustrated in figure 2 have been chosen because of uniformity in gradation and terminology in both periods. Because of the greater detail in figure 2, certain commodities shown in figure 1 have been omitted. Sodium cyanide is omitted because the price remained constant in the second period.

PRICE FLUCTUATIONS: In the first war period, copper sulfate was $0.05 per pound in January, 1914, dropped to 8.045 in October of that year, reached a peak of $0.22 in February, 1916, then dropped back to $0.0975 by the end of the war. Lead arsenate rose from $0.11 per pound in January, 1914 to $0.36 in May, 1918, where it remained until the end of the war. Pyrethrum started at $0.40 in January, 1914, raised to $0.52 in May, 1917 and dropped to $0.36 in December, 1918. Calomel ranged from $0.69 per pound in January, 1914 to $3.43 in March, 1916 and dropped to $2.00 by December, 1918.

The second war period shows a sharp contrast to the prices of the first period. Copper sulfate rose from $0.041 per pound in June, 1939 to $0.055 in August, 1941 and was reduced by price regulation to $0.05 early in 1943, at which level it has been maintained. Lead arsenate was $0.11 per pound in 1939, dropped to $0.085 for a short time in 1940 and has been held at $0.115 per pound since February, 1942. Pyrethrum powder rose from $0.27 per pound in January, 1939 to $0.37 in October, 1939, dropped back to $0.21 in November, 1941 and has remained at about $0.28 since early in 1942. Calomel ranged from $1.36 in January, 1939 to $2.96 per pound in May, 1943 and has remained at this level to date.

DISCUSSION AND SUMMARY: Chemical prices during the first war period advanced sharply because of heavy demands without corresponding increases in supply. This was due to a general lack of facilities and raw materials throughout the chemical industry. Reserve stocks were low and only a few chemicals were put under government control. No systematic attempt at allocation of stocks was made. The natural result was sharp increases in price following strong demand.

During the period between 1918 and 1939, the chemical industry was greatly strengthened and expanded. Instead of depending upon Europe for heavy chemicals, dyes and potash salts, the industry had now become largely self-sufficient. Domestic sources of raw stocks were developed and factories were expanded. Large reserves of a number of chemicals and metals were accumulated and required only to be assembled and placed in trade channels.

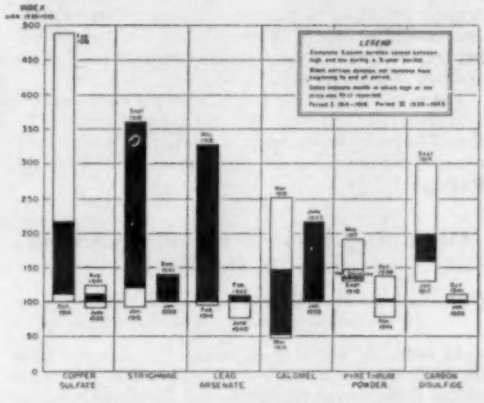

FIG. 2.—Fluctuations of insecticide prices during World Wars I and II. (Source: Indices are based on prices in the *Oil, Paint, and Drug Reporter*.)

The second war period has been characterized by systematic allocation of supplies and also by price control through governmental agencies. The control of prices, in the first war period, was attempted with only a few chemicals but in the present war, has been extended to include almost all commodities. Rigid control of prices was at first instituted by agreement between governmental agencies and manufacturers, followed by the "freezing" of existing prices of March, 1942 under the General Maximum Price Regulation and by subsequent special regulations.

The ultimate result of these years of planning and expansion, together with systematic allocation of supplies and price regulation, has been a tremendous growth in production with but moderate advances in price.—8-22-44.

The Attraction of *Cotinus nitida* by Caproic Acid

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While bait tests were being conducted on *Popillia japonica* Newman at the University of Maryland in the summer of 1942, numbers of the green June beetle *Cotinus nitida* L. were noted in traps containing technical caproic acid. A separation of approximately one quart on the basis of sex gave a 50-50 ratio. As this occurrence was noticed late in the season no counts were made the first year. Records were taken, however, in the summers of 1943 and 1944 and the data appear significant.

In 1943 Japanese beetle test traps containing caproic acid were checked carefully for the green June beetle. Two traps operated from June 28 to August 14 caught a total of 1168 beetles, or an average of 584 per trap for the period. Four traps operated from July 10 to August 14 caught 400 beetles, an average of 100 per trap.

A separate test was set up in 1944. It contained ten traps, five baited with dilute caproic acid and five unbaited. The acid was diluted 50 per cent with light white mineral oil (Saybolt viscosity 125–35) to reduce the rate of evaporation. The traps were arranged in a linear battery near a clump of wild grape. Records were taken daily from June 24 to August 12. The five traps containing dilute caproic acid caught a total of 346 beetles, an average of 76.2 per trap while the empty traps caught 12 beetles, an average of 2.4 per trap.

From the data collected it appears that caproic acid definitely attracts the green June beetle. The size of funnel opening and capacity of container may require modification for greater efficiency of the traps.—11-8-44.

Obtaining Freshly Formed Codling Moth Pupae

G. J. HAEUSSLER, *U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*

In breeding pupal parasites of the oriental fruit moth and the codling moth, freshly formed pupae of the former host species were readily obtained as needed by incubating hibernating larvae that had been held in storage at 42° F. Approximately 75 per cent of such larvae transformed to pupae on the sixth day when incubated at 80° and a relative humidity of 70–80 per cent. Considerable difficulty was at first encountered in forcing hibernating codling moth larvae to pupate, but the following technique was found suitable for obtaining quantities of freshly formed pupae of that species as needed. It is believed that this method might prove useful to others requiring supplies to codling moth pupae for any purpose.

Hibernating codling moth larvae, trapped late in the summer and early in the fall in corrugated paper bands placed on the trunks and larger limbs of apple trees, were removed from their cocoons and concentrated in lots of approximately 500 in packs composed of half-inch strips of white, semitransparent corrugated paper held together by rubber bands. The strips were placed together in such a manner that the only openings were those afforded by the corrugations, thus preventing the larvae from spinning between two strips, and the edges of the packs were strengthened by strips of fairly heavy, waxed pasteboard. The battery jars in which the larvae were confined with the empty packs were held at approximately 80° F. for 24 to 48 hours, to allow all the larvae to enter the corrugations and construct cocoons. After this had been accomplished they were stored at 42° until needed.

Upon removal from cool storage the packs containing cocoons were completely submerged in a pan of water for 2 hours, then placed in battery jars and held at 80° F. for several hours, frequently overnight, to allow the larvae to absorb moisture and to permit draining of the excess water. While the paper was still soft from the absorbed moisture, the strips forming the packs were separated and spread on paper toweling on a table in a warm room, where they were left until the paper dried out sufficiently to begin to stiffen. If allowed to become thoroughly dry while still in packs, the strips adhere tightly, and it is then impossible to separate them satisfactorily. Some migration of larvae occurred as the strips were drying, but these larvae were collected and allowed to spin new cocoons in fresh strips of corrugated paper. After drying, the strips were held in battery jars in an incubator at 80°, at a relative humidity of approximately 80 per cent, where pupation usually began on the seventh or eighth day following removal from storage. By holding the individual strips between the operator and the light, such as that from a window, the cocoons containing pupae could be readily detected and the sections containing them could be cut out. Pupae were removed in this manner once in every 24 hours. By this method, one worker could examine approximately 800 cocoons per hour, and approximately 10 per cent of the cocoons were found to contain pupae at the end of each 24-hour period. The pupae could then either be left in the cocoons or readily removed, as desired.—8-23-44.

The Attraction of *Verbena bonariensis* to the Imported Cabbage Worm

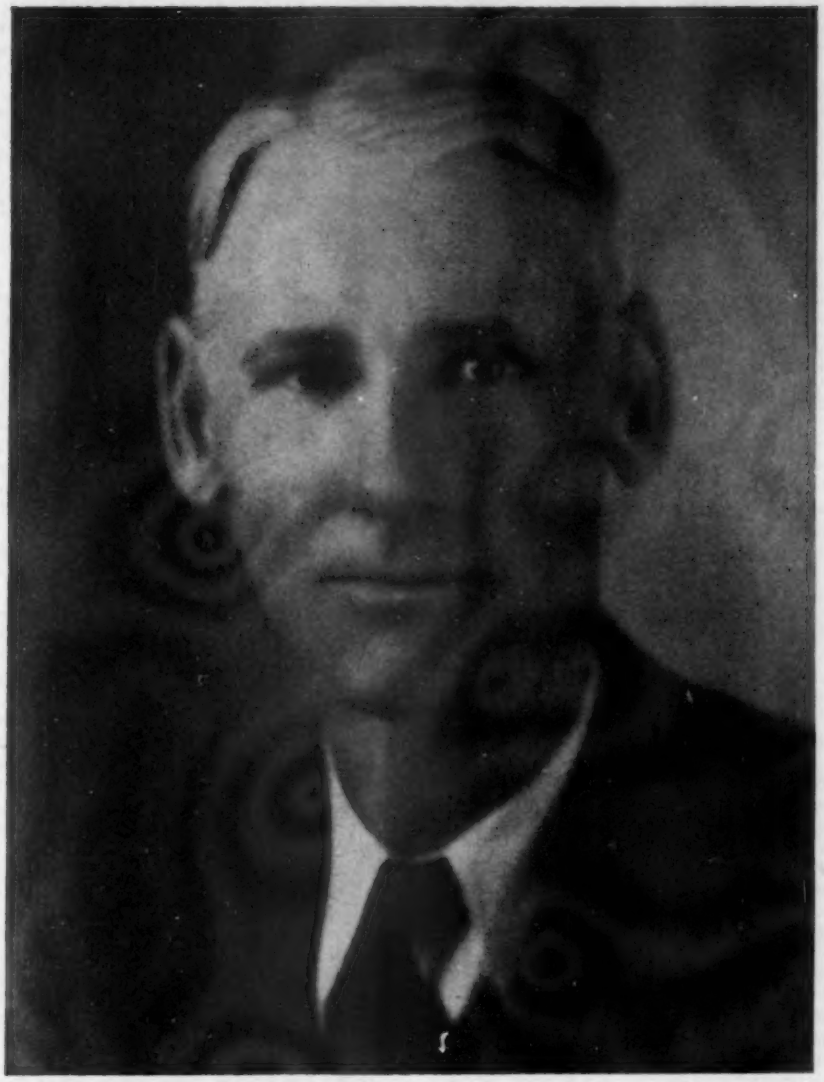
CLARENCE O. BARE

Each season, from late May to the middle of June during 1934 to 1939 inclusive, butterflies of the imported cabbage worm, *Pieris rapae* (L.), were noted feeding in great numbers upon the flowers of a roadside weed, *Verbena bonariensis* (Z.), near Charleston, S. C. Occasionally they were seen feeding upon cabbage or collard blossoms, thistles, *Bidens* sp., wild aster, or other wild flowers, but never in such large numbers. This exotic weed was identified by Dr. J. K. Small. It grows in abundance in waste places, often from 3 to 5 feet tall, and bears considerable purple inflorescence. Since it is so attractive it seems probable that its flowers may contain some substance that could be used as a bait for this insect.

SOUTHERN WAR CONFERENCE ON ENTOMOLOGY

The second Southern War Conference on Entomology was held in New Orleans, Louisiana, on January 24 and 25, 1945, with headquarters at the Roosevelt Hotel. This Conference is sponsored by the Cotton States Branch of the Association. A more detailed account of this Conference will appear in the February number of the *Journal*.

OBITUARIES



Charles Emerson Sanborn, 1877-1944

On July 5, 1944, Charles Emerson Sanborn died at his home in Stillwater, Oklahoma, ending 35 years of service to the state as a teacher and scientist in the field of biology. For 25 years, from 1909 to 1934, he was head of the Department of Entomology of the Oklahoma A. & M. College. During this period he served as Dean of the School of Agriculture, and Director of the Agricultural Experiment Station several times. He organized the graduate school and acted as its chairman for many years.

Professor Sanborn was born at La Plata, Missouri, April 16, 1877 and received the A.B. degree from Kansas University in 1903 and the A.M. degree in 1904. From 1905 to 1909 he was Co-operative Entomologists for the Texas Agricultural Experiment Station and Acting State Entomologist in 1908. In 1909 he was employed by the U. S. Bureau of Entomology and was stationed in Illinois.

Sanborn's interest went beyond the field of entomology. He was intensely interested in wildlife conservation and the great out-of-doors. He was President of the Oklahoma Wildlife Federation from 1937 when it was organized, until his death. He was a Director of the National Izaak Walton League of America and a National Director of the Boy Scouts of America. He was one of the founders of the Oklahoma Academy of Science and was its president in 1924–25. He was a member of Phi Sigma, Phi Kappa Phi and Sigma Xi and the American Association of Economic Entomologists from 1909 to 1926.

Sanborn was one of the best liked faculty members of the Oklahoma A. & M. College. He was in great demand as a speaker at boy's camps, wildlife conservation meetings and at agricultural extension short courses. He was a very effective radio speaker and his programs received enthusiastic comments from listeners in the neighboring states as well as in Oklahoma.

Perhaps his best scientific accomplishment was the discovery that horse flies were important vectors of Anaplasmosis, a disease of cattle. Although much criticism was directed at his findings, later work proved that he and his co-workers were right. He was especially interested in the Aphididae and his publication in 1904 on this family was a noteworthy contribution summarizing what was known at that time about this interesting and important group of insects.

In his passing, we all feel that a great and true friend of Oklahoma has gone. Among many tributes paid to him was a special broadcast made in his honor by KVOO in Tulsa.—F. A. FENTON.

Dwight Sanderson, 1878-1944

Dwight Sanderson,[1] past president of the American Association of Economic Entomologists, was born in Clio, Michigan, September 25, 1878, the son of Rev. John P. and Mrs. Alice Sanderson, and died at his home in Ithaca, New York, September 27, 1944. In his life span are included noteworthy careers in three rather distinct fields, those of economic entomology, academic administration and rural sociology. He received the degree of bachelor of science from Michigan Agricultural College in 1897 and of bachelor of science in agriculture from Cornell University in 1898. From Cornell he went directly to the Maryland Agricultural College as assistant state entomologist, and during the summer of 1899 was employed by the Division of Entomology as an assistant. In the fall of 1899 he became entomologist at the Delaware Agricultural Experiment Station at Newark, where he remained until 1902, during part of which time he was associate professor of zoology in Delaware College. In 1902 he became State Entomologist of Texas and professor of entomology in the Texas Agricultural and Mechanical College, College Station, for a period of two years. He then became professor of zoology in New Hampshire College (now the University of New Hampshire) at Durham, and three years later Director of the Agricultural Experiment Station at that institution, where he remained until 1910. That autumn he became Dean of the College of Agriculture at West Virginia University and, in 1912, Director of the Agricultural Experiment Station, where he remained until 1915. Just prior to leaving New Hampshire he was elected president of the American Association of Economic Entomologists and presided at the twenty-third annual meeting at Minneapolis, where he presented his address on "The Work of the American Association of Economic Entomologists," a timely and thought-provoking presentation.

His first book, *Insects Injurious to Staple Crops*, appeared in 1902. In 1911 he wrote *Insect Pests of Farm, Garden and Orchard* and *Elementary Entomology* with C. F. Jackson.

A bibliography of Sanderson's bulletins, articles and reviews on entomology and administration numbers just one hundred. While at New Hampshire he became interested in the effect of temperature on the distribution, hibernation and rate of growth of insects and he presented an extensive paper to the Association on this in 1910. Sanderson also wrote various articles and bulletins on urgent entomological problems of an economic nature, including work on the codling moth. His articles on entomology declined in number after he took up administrative work.

Sanderson took an active interest in the administrative and organizational affairs of the Association and was one of the prime movers in the founding of the JOURNAL OF ECONOMIC ENTOMOLOGY. He prepared and presented to the Association a plan whereby the JOURNAL could be financed. This plan was adopted and the first issue of the JOURNAL appeared in February, 1908. Sanderson became business manager of the new publication and held this post until 1911. He was also active in the movement to standardize insecticides, this culminating in the insecticide act, and to this task he brought sound common sense and practical ability.

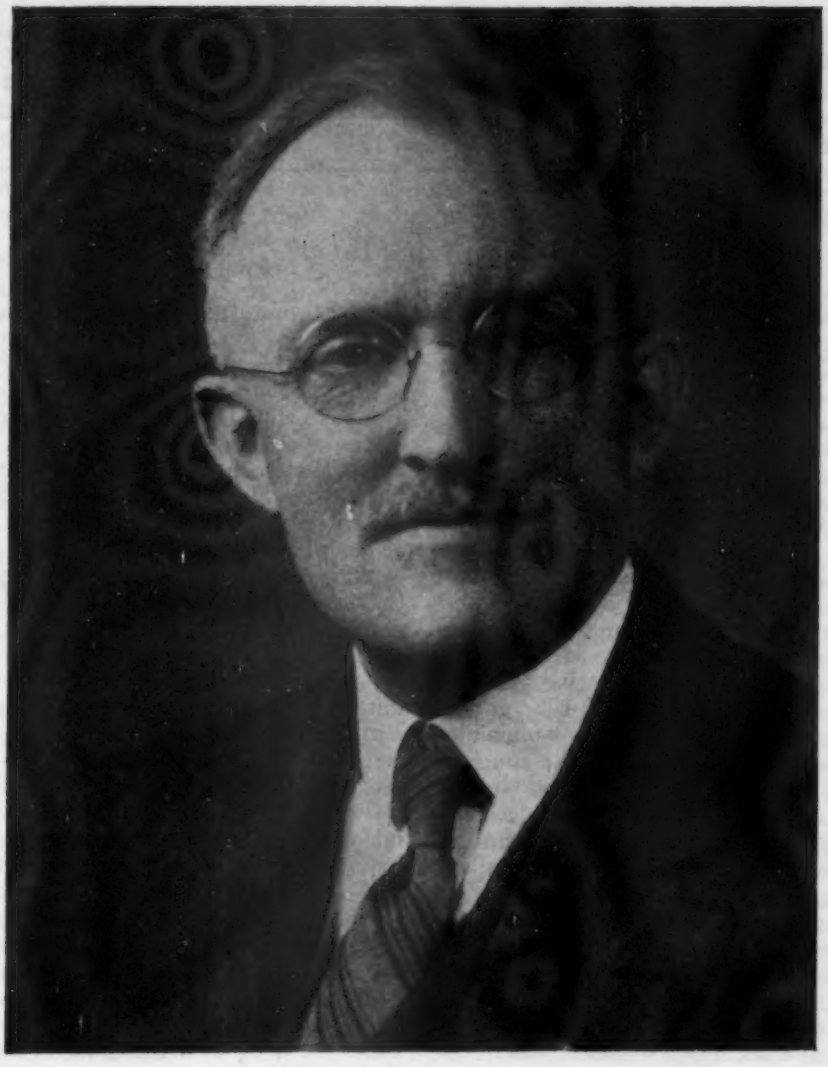
Administrative duties in agricultural institutions and consequent wide contacts with all phases of agriculture and with people caused his interests to broaden and to undergo some changes, especially because of his determination to make American farms still better places in which to live. This change of emphasis was a distinct loss to economic entomology but a gain to another field of activity. In 1915 he entered the University of Chicago to take graduate work in sociology. From this institution he received his doctor's degree in 1921. In 1918 he became head of the newly organized work in Rural Social Organization at Cornell where he remained until his retirement in 1943. In this third period of his career he was widely recognized as a leader in a new and uncharted field. Under his leadership, work in this field at Cornell assumed high rank, as attested by the large number of graduate students who worked under his direction, many of whom now hold positions of responsibility. After his retirement, Sanderson went to Florida for a short time but intended to return to Ithaca for permanent residence when, on his way north, he was stricken and removed from the train at Baltimore. Later he completed the trip home but survived only a short time.

In his last field of endeavor he wrote *The Farmer and His Community*, 1922, *The Rural Community*, 1932, and *Rural Community Organization*, 1939. Later he wrote a book, *Rural Sociology and Rural Social Organization*, 1942, a text-book in rural sociology. He and his students prepared a series of monographs on the rural community. He edited the proceedings of the First National Country Life Conference, 1927, and wrote a total of 86 articles, bulletins and reports in the field of rural sociology.

Sanderson married Anna Cecilia Blandford of Prince Georges County, Maryland, September 19, 1899, who survives him with their only child, Alice Cecilia Sanderson, also of Ithaca.

This categorical account of a busy life fails to reveal some of the things that his friends and colleagues knew about Dwight Sanderson, and some of the influences in his life that dictated his course. He was the son of a clergyman of the Congregational denomination and a member of a family of socially

[1] Ezra Dwight; for many years he signed his name "E. Dwight," later abandoning the first initial.



DWIGHT SANDERSON, 1878–1944

minded people, his two younger brothers both being engaged in work for other people rather than for themselves. His genuine interest in rural people led him to seek means whereby their lives might be broadened and lifted to a higher plane. His chief contribution to rural life was, perhaps, emphasis on the building of the natural rural community in which the centralized school becomes a major factor in community unification. Aside from his official tasks Dwight Sanderson was known to the communities of which he was a part as a public spirited citizen, ready and ever willing to carry more than his proportionate share of civic and social responsibilities. In Ithaca, where he spent his more mature years, he was at various times chairman of the Council of Social Agencies, president of the Social Service League operating two settlement houses, director of the Community Chest and of the Family Welfare Society, and organizer of the Town and County Social Workers Club. This incomplete list of the more public aspects of his beneficence suggests his broad community interests and the recognition of his usefulness by his fellow citizens.

Perhaps the characteristic for which Dwight Sanderson will best be remembered by friends and colleagues with whom he was most closely associated was his cordial good will. He was a great friend, held in genuine affection by a host of associates and fellow citizens, among whom are many of the older entomologists who recall his cordiality and cooperative spirit when he was an intimate part of the entomological profession.—E. F. PHILLIPS.

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After the War—What?

THE PROGRESS of entomology throughout the wartime period has abundantly justified the hope that our science will be, after the war, a much more essential part of the life of the nation than ever before. Why this must be true is well enough known to every entomologist not to require detailed discussion here.

Our Association has recognized the obligation that is implicit in this public realization of the importance of entomology and has constituted a committee to study post-war problems and to formulate post-war plans. This committee may be expected to report its tentative plans to the Association from time to time and to have a very definite series of recommendations for our consideration. The committee will doubtless include in its list of projects several which will be designed to take advantage of the opportunities which will be peculiar to the immediate post-war period, Among these may be some large-scale extermination campaigns requiring, for a limited period, a large increase in man-power and in public support. These will be of double value to the nation in that they will accomplish entomological work which would be out of the question in normal times and, at the same time, take advantage of the "fluid" condition of manpower during a period of readjustment and relocation of entomologists and the men in other fields who may be needed to cooperate in any large-scale operation.

It is not too much to say that we expect some really sensational developments in insect control to materialize in the years immediately following the demobilization of the armies. And these may even be started with the partial demobilization which will doubtless follow closely on the defeat of Germany. Just what these projects may be will depend in large part upon the findings and recommendations of The Committee on Post War Planning and it is not our purpose to discuss them further at this time.

There is always a tendency, in any group, to shift the responsibility for work to the shoulders of a committee and to forget that each person back of that committee has his share of responsibility in the activities of the committee and in the *action* which must follow the formulation of plans. Entomologists may be expected to accept this responsibility in this instance just as they have in the past. Certainly they have amply justified this expectation in the experience ofthe Committee for Coordination of Entomology with the War Effort where they have so conspicuously carried on where the Committee necessarily left off.

The membership of the Association may properly be said to have constituted itself a Committee of the Whole, to put into effect the recommendations of the Coordination Committee. Is it too much to suppose that they will do the same with the Post War Committee? Our faith in the profession of entomology, tells us no.

But even the best of us may be, at times, in need of a reminder of the fact that willingness to cooperate is not enough. That cooperation, to be effective, must be prompt, it must be actively interested, it must be ready to assume such part of the leadership in any project as requires delegation, it must contribute ideas as well as labor because no committee can foresee all the details of the requirements of any project. It must expect local leadership to supplement, to modify, the plans of campaign as changing local conditions indicate. Here, too, we have faith in the Entomologists. We believe that they will fully live up to expectations in any circumstances which may develop even in work of national and international scope.

Cooperation may, however, be a little more ready to make itself apparent if we think of the future in terms of tomorrow rather than of next month or next year. If we make ready *now* for what is ahead. We have a Post War Planning Committee, necessarily restricted in its membership. Why not, *now* constitute ourselves into a Post War *Action* Committee, including all members of the Entomological Profession? And make it apparent to those to whom the leadership, planning, has been delegated, that we are ready, at any minute, to go along with them and develop their plans into realities?

We have already discussed, vaguely, what may be involved in certian phases of a post war program. But we have not mentioned post war activities which will face every entomologist. We have stressed the sensational, in which we will all be interested but in which we may not all, or even many of us, participate directly. Even more important will be the activities before each one of us.

And what are these? The answer is simple. Our post-war programs, in most cases, will be very similar to our war-time programs and our pre-war programs. Daily routine in research, restricted in its scope, so far as any one individual is concerned, unsensational in its results, monotonous in its nature. But none the less, the backbone, now and always, of any entomological program designed to serve the people. The Chairman of the Post War Planning Committee addressed the Pacific Slope Branch of the Association on the subject of Post War Entomology last summer. His talk included little that was new, nothing that was sensational. And, probably for this reason, it presented to anyone who will give the matter his attention, a very good picture of post-war entomology as it will seem to the individual entomologist. Just a few new activities, interwoven with our previous ones. Then a little more pressure all along the line; a little more effort—much more effort, to promote the actual use of the standard practices developed in the past and still effective. Harder work and more of it and very little limelight, for the most of us. That is post-war entomology. If this discussion will insure a more careful study of Mr. Rohwer's paper, published in this number of the JOURNAL, it will have served its purpose.

Entomology for Entomologists or Entomologists for Entomology?

THE SCIENCE of Entomology is providing vocations for thousands of trained men and women. And yet as we examine the lists of those who receive a livelihood from the study of insects, we become woefully aware that too large a number are not supporting the science.

Labor, whether skilled or otherwise, is well organized and pays enormous sums for the support of their cause and their leaders. Entomologists, fortunately, do not have to pay for the support of their leaders, and yet hundreds—in fact perhaps a third of those who claim Entomology as a vocation—are not members of the American Association of Economic Entomologists. Contrast this with the percentage of medical men who are members of the American Medical Association.

Here in America we have two great national entomological associations, each supporting a publication of world importance. The American Association of Economic Entomologists and its official publication. THE JOURNAL OF ECONOMIC ENTOMOLOGY, deals with the insect problems of economic importance. The dues, which include subscription to the JOURNAL and the quinquennial bibliography of economic entomology volume, are five dollars. The Entomological Society of America and its valuable Annals, deals largely with the problems of insect taxonomy, morphology, physiology, and biology. The Society dues, including subscription to the Annals, are four dollars. Every entomologist, whether dealing largely with applied entomology or with the "pure" science of entomology is morally obligated to support both societies, because one is dependent upon the other. And where will one receive as much for nine dollars as membership in these two national societies and two publications, totaling some 2000 pages of the most valuable and up-to-date information in the science of their choice? In addition to the advantages and returns received from membership in these

associations, it should not be forgotten that such memberships also give the privilege of publication in the serial publications referred to.

Another entomological activity which has received very meagre support is the Thomas Say Foundation. This Foundation was organized to publish technical monographic volumes which are not acceptable by commercial publishers because they do not have a large demand and the financial returns are not adequate. We must remember that such publications are essential to progress in our science and warrant the support of everyone who is dependent upon Entomology for his livelihood.

The seventy per cent of the entomologists supporting our association are assuming the financial burden for the entire science. The science of Entomology should be supported by all interested in Entomology, and we commend to the officers of both national societies the suggestion made by Doctor Campbell in his editorial in the April 1944 issue of the JOURNAL. His suggestion does not obligate either organization, but offers an opportunity for the study of a problem of great importance to Entomology.

Perhaps entomologists in strategic positions, and industry as well, might include in their qualifications for employment, membership in our national associations as an assurance of the prospective employees' interest in, and support of, their chosen profession.

J. J. DAVIS

TWELFTH ANNUAL MEETING NATIONAL PEST CONTROL ASSOCIATION

The 12th Annual Meeting of the National Pest Control Association, under the presidency of George R. Elliott of Worcester, Massachusetts, was held at the Sherman Hotel, Chicago, Illinois, October 23, 24, and 25. There were a total of 603 registrations and the entire program was planned around the four basic themes:

1. Tomorrow's Tools—Materials and Methods
2. War's Backwash—Insect Borne Diseases
3. One Common Language—Standards
4. Back to a Racket—or On to a Profession

Entomologists and biologists who participated in the program included, Guy F. MacLeod, George C. Decker, W. E. Dove, B. G. Berger, F. E. Garlough, G. C. Oderkirk, A. M. Day, J. J. Davis, Geo. E. Gould, and M. H. Doner.

Briefly, the subject discussed included new chemicals for the P.C.O., including DDT, fumigation practices, termites and powder post beetles, rodent problems, moths and carpet beetles, roach control, bedbug control, and post-war plans.

A major feature was a report of the research committee which was responsible for a highly successful industry research program with DDT and mothproofing.

Dr. W. E. Dove of the U. S. Bureau of Entomology and Plant Quarantine and Father Ovile Fournier of Montreal University were awarded honorary memberships.

J. J. Davis, for Purdue University, was presented with a complete suit of medieval armor or "Coat of Mail," a piece of equipment he has been trying to acquire for some time to use in classroom work to demonstrate the external skeleton of insects and its relation to insect control.

Entomologists who attended the meeting in addition to those listed above included, Eugenia McDaniel, W. J. Baerg, E. M. Searls, and W. J. Gerhard.

TO READERS OF THE JOURNAL

The article entitled "The Locust Plague," by Dr. B. P. Uvarov, published in the JOURNAL for February, 1944, was previously published in the Journal of the Royal Society of Arts, London, vol. XCI, pp. 109–16.

The article was submitted to the JOURNAL OF ECONOMIC ENTOMOLOGY by the British Information Services, New York, in the guise of a new and unpublished manuscript. It was accepted and published after some correspondence with the agency which had submitted it and which seemed very anxious to secure publication, even though it was slightly out of line with the papers commonly accepted and published by our JOURNAL.

Some months later Dr. Uvarov wrote the editor. He stated that the paper had been published without his knowledge or consent and that it had previously been published with acknowledgment and without the consent of the Journal in which it first appeared.

Dr. Uvarov was concerned mainly with the fact that the paper had been prepared as a semi-popular paper, not as one for professional entomologists, and he feared that his American colleagues would feel that he had been "writing down" to their level.

The circumstances under which publication in the JOURNAL OF ECONOMIC ENTOMOLOGY was permitted have been made clear to Dr. Uvarov and to the Journal of the Royal Society of Arts and they are satisfied that there was no intentional disregard of their rights or of the common courtesy of an acknowledgement for a previously published article.

The editor is indebted to Dr. Uvarov for his cordial acceptance of the explanations offered and his courtesy at all times, even before the explanation of the circumstances was known to him.

It may be added that one motive in the acceptance of the article for publication was our desire to promote, in every possible way, the international amity which has always existed between the British and the American members of our profession.

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